UNIVERSITY OF CAPE COAST

URBANISATION AND QUALITY OF RAW WATER: A CASE OF WEIJA RESERVOIR

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BY

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Thesis Submitted to Department of Geography and Regional Planning of the Faculty of Social Sciences, University of Cape Coast in partial fulfillment of the requirements for award Master of Philosophy degree in Geography and Regional Planning

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DECLARATION

Candidate's Declaration

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

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

Name: Lord Ebow Sampson

Supervisor's Declaration

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

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

Name: Dr. Benjamin Kofi Nyarko

Co-Supervisor's Signature: ………………………… Date: …………….

Name: Prof. Laud A. Dei

ABSTRACT

The increase in population within the Densu River Basin (DRB) from 450,000 in 1984 to 947,000 in 2000 shows an average yearly growth rate of 3.26%. This therefore has resulted in the increase of anthropogenic activities which have caused contamination with regard to the quality of water of the Weija reservoir. Using a descriptive study design, this study aimed at establishing relationships that existed between urbanization within the DRB and the quality of raw water from the Weija Reservoir for a 14-year period (2002-2016). The study used sixteen (16) water quality parameters, as well as some urbanization parameters such as population and land Use/Cover changes and finally, views of respondents from some sampled communities. The study revealed that water from the Weija Lake has been less influenced by urbanization in the DRB, putting into consideration water quality parameters such as phosphorus, nitrate, ammonia, magnesium, calcium, total hardness, fluoride, iron and sulphate. It was also realised from the study, that the quality of water in connection with parameters such as turbidity, colour, pH, temperature, suspended solids and total solid had been influenced extensively by urbanization for the 14-year period. In view of this, it is recommended that Stakeholders of DRB such as the Densu River Authority (DRA), the Ghana Water Commission (GWC), the Weija Head Works (WHW) and the District Assemblies should ensure that sustainability of quality of water from the Weija reservoir is achieved through clean integration of social, environmental and economic developments as emphasized in the definition given by the Bruntland commission.

KEY WORDS

Land Use/Land Cover

Raw water

Reservoir

Urbanization

Water quality parameters

Weija

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DEDICATION

To my family.

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LIST OF ACRONYMS

AAS	Atomic Absorption Spectro-photometer
AGC	Ashanti Gold Company
AOI	Area of Interest
APHA	America Public Health Association
CSIR	Council for Scientific and Industrial Research
DFID	Department for International Development
DRA	Densu River Authority
DRB	Densu River Basin
ETM+	Enhance Thematic Mapper Plus
GIS	Geographic Information System
GSBA	Ghana Standard Board Authority
GSBGV	Ghana Standard Board Guideline Value
GWCL	Ghana Water Company Limited
HDM	Human Development Making
LULC	Land Use- Land Cover
mg/L	Milligram Per Litter
MSS	Multispectral Scanner
NTU	*Nephelometric Turbidity Units*
OLI/TIRS	Operational Land Image/ Thermal Infrared Sensor
PCA	Principal Component Analysis
RS	Remote Sensing

SPSS	Statistical package for Social Sciences
TCU	True Colour Unit
TDS	Total Dissolved Solids
TIA	Total Impervious Area
TM	Thematic Mapper
TS	Total Solids
TSS	Total Suspended Solids
USDC	United State Department of Commerce
USESB	United State Environment Studies Board
USGS	United State Geological Survey
UV	Ultra Violet
WHO	World Health Organisation
WHW	Weija Head Works
WRC	Water Resource Commission

CHAPTER ONE

INTRODUCTION

Background to the Study

Water is an important natural endowment available to mankind and of high significance to food production, human livelihoods, and the preservation of life and natural surroundings. However, the influences of anthropogenic factors have affected the quality of water resources in many regions of the world (Piao, Ciais, & Huang, 2010). Worldwide projections have revealed that water consumption for most users will rise by at least 50 percent by 2025 compared to its level of usage in 1995 (Rosegrant, 2002).

Although small fraction of the earth's land surface is covered by urban features, current urban growth has meaningfully impacted the natural landscape, leading to considerable variations in the environment and associated ecosystems at the various geographical scales (Lambin et al., 2001). The world's urban population has grown above 400 percent since the 1950's and that is to 3.9 billion currently. According to Rosegrant, (2002), by the year 2025, about 60 percent of the world's population is expected to live in urban areas.

It has become increasingly essential to comprehend the impacts of urbanization on the functions and structure of natural resources, the society, and culture as a whole (McDonald et al., 2011). Urban cores often develop along water bodies because of their ability to get water for all sorts of human activities such as washing, cooking, drinking and transportation. Over the last two hundred (200) years, urbanization has caused changes in river properties around the globe. Such changes include decline in the natural filtering ability of river systems (e.g., loss of floodplains, channelization of headwater streams and inability to make available quality water) and the regulation of its flow due to the construction of dams and impoundments. These changes have caused watershed sediment and solute export to be altered globally. Again, urbanization in general, emanates with an increase of watershed total impervious area (TIA), in the form of roads, lawns, rooftops as well as parking lots.

According to O'Driscoll, Clinton and Jefferson (2010), urbanization disturbs surface water dynamics and quality, the recharge from groundwater, the ecology, geomorphology, and the biogeochemistry of streams and rivers. Consequently, there is an impact on water quality and watershed functions (Sun & Lockaby, 2012). Clearing of forest lands for urban usage results in an increase in surface albedo, enhances summer storm intensity, decreases net radiation, reduces latent heat and causes heat island effects (O'Driscoll *et. al.*). These factors bring about dramatic changes in the quality of water (O' Driscoll et. al.).

Water quality is a significant parameter which touches on all features of ecosystems and human well-beings such as economic activities, biodiversity and the health of people in a community. Therefore, the quality of water is very important in defining the wealth of a people, their educational heights and even how poor they are. In respect of this, water needed for recreation, drinking, fishing and also serving as the habitat of aquatic organisms need to meet a certain criteria. Water quality is defined as the chemical, physical, and biological features of water that is needed to sustain desired water uses (United States Environmental Studies

Board [USESB], 2003). It is worth noting that after water has been used, it often finds its way back to the hydrological system and therefore if the water is not treated it ends up affecting the environment.

The quality of water worldwide is reducing mainly as a result of human actions such as quick growth in urbanization, increase in population growth and the release of new chemicals and new pathogens from invasive species and industries (Piao et al., 2010). In recent times, Ghana has experienced a continuous encroachment on protected areas along water bodies and this has been a major problem for the country. According to Walker (2001), there exist two key factors that are considered as driving forces for the encroachment of land in the world, and these are; the demand of land for agricultural production and the demand of land for residential purposes.

Statement of the Problem

Push-pull factors have triggered the movement of some activities from the urban core to the periphery (counter urbanization) (Walker, 2001). This attitude of humans has continuously led to the building of structures and establishment of farms along river banks. The River Densu from which the Weija Reservoir gets its water is no exception. According to Anon (2002), the increase in human population within the Densu River Basin (DRB) from 450,000 in the year 1984 to 947,000 in 2000 shows a yearly growth rate of 3.26%. This has resulted in so many environmental challenges confronting the river basin, principal among which are deforestation, pollution and land encroachment. Due to the poor waste disposal practices of communities within the DRB, the river has been turned into a refuse receptacle as it was indicated by Asante et al., (2005), with people pouring anything unwanted into it. As a matter of fact, the pollution occurs along the entire course of the river, until everything eventually assembles in the reservoir (Anon, 2002).

The raw water acquired directly from the reservoir to satisfy the needs of the fast growing populations in urban areas changes in quality in accordance with the level of pollution of the River Densu (Department for International Development [DFID], 1999). This situation, to a large extent, has been attributed to anthropogenic activities (Asante, Quarcoopome, & Amevenku, 2005). Such activities include municipal and industrial liquid and solid wastes, indiscriminate dumping of domestic wastes, improper land use, environmental degradation and poor agricultural practices along the basin of the river and also within and around the reservoir's catchment. A major physical evidence of change in the quality of water produced by the Weija Reservoir is the high level of green filamentous algae (eutrophication) that could be seen on the surface of the water. Records indicate that GH ¢ 40,000 (Forty thousand Ghana Cedis) is spent every day to treat water at the dam before it is supplied to consumers (Chronicle, December 23, 2011 pg. 6).

The quest to improve the quality of water in the Weija reservoir had resulted in the conduct of many studies. Many years after urbanization within the DRB and also around the catchment of the Weija reservoir, questions such as; what has been the trend of land use - land cover? What has been the trend in the quality of raw water and finally the relationship between urbanization within DRB and the quality of water in the Weija reservoir over a 14-year period are deemed necessary to be answered. It is in this light that this study was embarked upon.

Rational of the Study

Reservoirs are either man-made or natural lakes which serve vital economic and environmental purposes. Their importance includes provision of water for irrigation purposes, fish farming, potable water supply, and hydroelectric power generation. In the last forty (40) to fifty (50) years, many reservoirs such as the Volta reservoir, Barekese, Kpong and Weija reservoirs have been established in Ghana by creating dams in some rivers (Asante et al., 2005). The fresh water that is obtained from these reservoirs to satisfy the needs of the fast growing urban population is low in quality due to pollution (DFID, 1999).

The study is thus aimed at establishing a relationship between the urbanization of the DRB and the quality of water of the Weija reservoir over a 14-year period.

The role of land use - land cover - changes in the study is to determine and measure where and when changes took place, where changes were pronounced, and understand the driving forces and mechanisms of changes from spatio-temporal scales (Agarwal, Green, Grove, & Evans, 2001). Remote Sensing and Geographic Information Systems allowed areas where changes were most intensive to be identified, mapped, and analyzed.

Research Objectives

The main objective of this study was to establish a relationship between urbanization and the quality of raw water for the Weija Reservoir**.**

Specifically, the study sought to:

- map land - use-land - cover types and changes within the Densu River Basin for the years 2002, 2007 and 2017
- analyze the trend in the quality of raw water over the 14-year period
- establish a relationship between the rate of urbanization and the quality of raw water over the 14-year period

Research Questions

- What are the land use/cover types and changes within the Densu river catchment for the years 2002, 2007 and 2017?
- What has been the trend in the quality of raw water over the 14 years?
- What has been the relationship between urbanization within DRB and the quality of raw water of the reservoir?

Significance of the Study

This study contribute to theory of sustainable development as it demonstrate to some extends some empirical evidence through which the Densu river and the weija reservoir are being sustained for future use. The study also contribute to land use - land cover knowledge of the study area as it provides empirical evidence of land covers and land uses of the Densu river basin.

Additionally, empirical findings of this study add to the knowledge base of trend in water quality parameters of the Weija reservoir over a long period, which is 14 years. This would greatly benefit researchers, especially those in water and sanitation as this would serve as a reference material.

The empirical findings is to also aid in the sensitization of stakeholders for improved basin and catchment management and proper urbanization measures as this will help the Weija Municipal assembly to achieve its vision of a well-integrated developed municipality as a model for social advancement, local economic growth and infrastructural developments in harmony with the physical and natural environments.

Delimitations of the Study

The study was conducted within the framework of establishing relationships that exist between urbanization in the DRB and the quality of water in the Weija Reservoir. It is a case study approach of one particular water body (Densu River) and does not cover similar water bodies. Therefore, this does not permit the results to be generalized but its findings to be placed in the relevant context of the individual water body being studied.

The year 2002 was set as the base year for the study because according to records at the Weija Head Works, it was the oldest year with existing and recorded data on the water quality parameters whilst 2016 was the year within which the study got started. So therefore the time frame (years) between these two years (2002 and 2016) was what the study was based upon, which was 14years.

All parameters that had consistent recordings throughout the 14 years were included in the study while parameters with inconsistency in recordings were excluded. Parameters that were included comprised Phosphate, Nitrate, Ammonia, Turbidity, Colour, and pH, Temperature, Sulphate, Iron, Fluoride, Total Solids, Total Suspended Solids, Total Dissolved Solids, Total Hardness, Calcium and Magnesium.

Lastly, Nsawam, which has many commercial farms was not involved in the study communities. This is because it was not captured after applying the sampling methods.

Limitations of the Study

The results derived from the analysis of the trend of the sixteen (16) parameters restricted the study to reveal a pseudo state of raw water in the Weija Reservoir for the 14-year period.

Also, the unavailability of 2016 satellite image made the researcher opt for the 2017 satellite image and in effect, prevented the true revelation of the land use/cover variations in 2016.

Organization of the Study

This research was structured into six chapters. Chapter One presented the background to the study, statement of the problem, and the objectives of the study. It also outlined the research questions, the significance of the study, as well as delimitation and limitations of the study. The second chapter reviewed relevant literature on the concepts and core issues of the study. Chapter Three gave explanations on how the study was conducted. It included the study design, study population, sample size and sampling procedure, source of data, and procedure for data analysis and presentation. Chapter Four is made of the analyses and discussions of the results on land-use land-cover variations. Chapter Five analyzed and discussed the results on water quality and the relationships between urbanization and water quality. Chapter Six captured the summary, recommendations and conclusion for the study.

CHAPTER TWO

LITERATURE REVIEW

Introduction

This chapter reviews literature on various concepts, terminologies, methods and models that are used in this study. It presents a review of the literature related to the issues of water quality and its parameters, and also, the definition of urbanisation and its impact on water. Some of the concepts addressed are in connection with the application of Geographic Information System (GIS) and Remote Sensing (RS) in Land-Use-Land-Cover mapping and variations.

Quality of Water

Water appears to be one of the most abundant and indispensable vital substances for the life of plants and animals. There could be no life without water. Water is used mainly by humans for domestic purposes like drinking, bathing, cooking and washing among others. Other purposes are irrigations, transportation, sewage disposal and recreation.

Potable water which should meet all the set standards by the World Health Organization (WHO) or by individual countries cannot be ascertained by just looking at the colour of the water, its taste or smell. This is due to the fact that there may be the presence of minute microorganisms like bacteria, viruses and fungi which cannot be disclosed by the senses but are commonly found in water.

These microorganisms are dangerous to human health and to the general environment than physical turbidity since they cause most of the known diseases on earth. Again, this pathogenic enteric bacterium enters the environment through many forms of anthropogenic activities and human or animal excreta (Dadswell, 1993). Therefore, water in the raw state or untreated state is a good medium that can accommodate various types of pathogenic and non-pathogenic bacteria and therefore before water can be rendered fit for domestic purposes or consumption; it needs to be adequately treated. Where no treatment is given to drinking water, then appropriate protection and management of water sources should be greatly taken into consideration to minimize pollution or contamination of water. This is very important because current data reveals that about 20% of the world's population lacks access to safe drinking water or adequate sanitation (Hunter, Colford, Lechevallier, Binder, & Berger 2000).

Water Quality Parameters

Physico-chemical qualities of raw water are essential in the choice of the best source and treatment that water needs as well as in the assessment of the degree of pollution (World Health Organization [WHO], 1984). Parameters that were considered in the study are discussed below.

Phosphate

Phosphates are generated from the remnants of organic pesticides which contain phosphates (United State Environmental Studies Board, 2003). They are often released from industrial and household cleaning, fertilizers and pesticides

(USESB, 2003). "*Naturally occurring levels of phosphates in surface water bodies are not harmful to human health, animals or the environment. Conversely, high levels of phosphates can cause digestive problems*" (Fadiran, Dlamini & Mavuso 2008). According to the authors, too much of phosphates concentration in water bodies can result in eutrophication (this is a condition whereby algae is produced in extreme quantities until they perish).

The presence of too much algae on surfaces of water can result in the formation of a scum which can cause pipelines to be clogged and produce a foul odor when they eventually decay (Sheila, 2005). Also, algae blooms have relations to health issues with examples being skin irritation and death of both human and animals depending on the duration of exposure and the type of algae bloom (Brian, 2005). Phosphate which happens to be greater than 100 mg/L may affect the coagulation process in water treatment plants. With reference to the World Health Organization (WHO) (2011), guidelines for drinking water quality (4th, Ed.), there is no exact guideline value for phosphate in drinking water but the WHO advises that phosphate in water should not be greater than 100mg/L.

Total Suspended Solids (TSS)

All suspended materials that range from 10 mm to 0.1 mm are termed as suspended solids even though in standardized laboratory tests, TSS is termed as the material that cannot penetrate a filter that has a diameter of 45mm. Suspended solids may be composed of materials such as silt, clay, organic compounds, inorganic compounds and plankton.

Naturally, changes in pH can influence the level of TSS. Changes that occur in the pH may cause some of the solutes to precipitate or will have an impact on the solubility of the suspended matter. Some of the human activities that cause the release of TSS include discharge from mining sites, industrial discharge and storm water runoff from human modified land surface. According to Ghrefat and Yusuf (2006), small scale mining activities are often responsible for the high levels of suspended solids in water bodies through the discharge of waste water from gold processing activities as well as run-off of clay or silt particles. Checking TSS of water is an essential criterion for assessing its quality. Solids that suspend on water surface absorb heat from sunlight which tends to increase the temperature level of the water. The minimum and maximum guideline value established by WHO (2011) is between 8.2mg/l-12mg/l.

Ammonia

Ammonia is known as a nutrient that contains hydrogen and nitrogen. Its chemical formula is NH_4^+ in the ionized form and NH_3 in the un-ionized form. Total ammonia is the sum of both NH_3 and NH_4^+. Naturally ammonia can occur in water through fecal matter, algae growth, animal matter and decay of plants. The presence of an amount of ammonia can also be affected by other aspects of nitrogen cycling.

Concentration of ammonia in water can also come from industrial, domestic and agricultural pollution; mainly from fertilizers and organic matters. According to Wake (2005), the harmfulness of ammonia often depends on pH, oxygen concentration and temperature. WHO has set 1.5mg/L as the maximum guideline for ammonia (WHO, 2011).

Turbidity

Turbidity of a water body is the reduction of transparency which has occurred as a result of the presence of particulate materials such as clay or silt, plankton, finely divided organic matter and also some other microscopic organisms (Putz, 2003). Turbidity measures the degree of light scattered by suspended particles such as clay or silt and can be referred to as the cloudiness of a water sample (Stanistski, Eubanks, Middlecamp, & Stratton, 2000). The maximum contaminant level ranges from 1 to 5 Nephelometric Turbidity Units (NTU) and according to WHO (2011), water with turbidity level greater than 5 NTU is termed not to be of good quality. High levels of turbidity may affect water treatments and disinfections and cause aesthetic problems. Because of the potential link of high levels of particles to bacteria, the level of turbidity is used to signal the potential microbiological contamination of a water body. The primary approval is that the turbidity level of water should not exceed 1 NTU (Stanistski et al.). The secondary approvals are based on odour, taste, colour, corrosivity, staining and foaming properties of water.

Anthropogenic activities such as logging, grazing, agriculture, mining, road construction, urbanization, and commercial constructions contributes to periodic pulses or chronic levels of suspended sediments in streams and other water bodies (Zoeteman, 1980). Drinking water with a higher level of turbidity is associated with higher risks of people developing gastro-intestinal diseases. This is especially problematic for immune-compromised people, due to contaminants like bacteria or viruses that can become close to the suspended solids (Stanistski et al., 2000).

Total Dissolved Solids

Total Dissolved Solids are known to be the remains in a weighed dish after the sample has been checked through a standard fiber glass filter and after which it had been dried to a fixed mass which ranges from 103 to 105 degrees Celsius. Many dissolved substances in water are unwanted (Putz, 2003). Minerals that had been dissolved in water, organic constituents and gases may create an aesthetically unpleasant odour, taste and colour. According to Putz, water that has higher dissolved solid content often has a laxative effect upon people who seem to be new to its usage. World Health Organization has set 1000mg/L to be the maximum level of Total Dissolved Solids in drinking water (WHO, 2011)

pH

It is a degree of the amount of hydrogen ion (H+) in water. Water is termed to be acidic when the pH value is low whilst water is more alkaline when the pH value is high. When pH levels of water is less than 7.0, corrosion of metallic water receptacles may occur, releasing metals into the water. According to WHO (2011), high or low levels of pH (less than 6.5 and greater than 8.5) may cause stomach pains. Because of the relationship between atmospheric gases, pH, and temperature, it is intensely required that the water be tested as soon as possible. According to Stephanie (1998), rocks such as granite and basalt are contributing factors to lower pH in a water body.

Sulphate

Sulphate (SO_4^{2-}) is termed as a mixture of oxygen and sulphur. It exists naturally in many soil and rock formations (Silberberg, 2000). The consumption of water that contains high amount of sulphate can have a laxative effect. This is enhanced when the sulphate is consumed in combination with magnesium (WHO, 1984). Some amount of sulphate dissolves into the ground as water moves through soil and rock formations that contains sulphate minerals.

Also, increase in human population and thus resulting in domestic and industrial activities undertaken by people contributes to the increase of sulphate concentrations in water (Okeola, Kolawole, & Ameen, 2010). Dehydration, catharsis and gastrointestinal irritation are the major physiological effects resulting from the ingestion of large quantities of sulphate. The permissible WHO guideline value is 250mg/l and any deviation may result in diarrhea (WHO, 2011).

Nitrate and Nitrite

According to WHO (2007), nitrate and nitrite existence in drinking water is more often as a result of excessive use of fertilizers in addition to incorrect farming practices and sewage. A high level of nitrate in drinking water is often associated with the simultaneous presence of bacterial contamination (WHO).

The main health danger of consuming water with nitrate/nitrogen happens when nitrate is converted to nitrite in the human body (WHO, 2006). The nitrite reacts with iron in the haemoglobin of the red blood cells to create methaemoglobin, which lacks the oxygen-carrying capacity of haemoglobin. The result of this is a condition known as methaemoglobinaemia, in which according to WHO (2006), is when blood lacks the ability to carry sufficient oxygen to the individual body cells which may cause the skin and veins to appear blue.

Most humans who are over one year of age have the ability to quickly transform methaemoglobin back to oxyhaemoglobin. Yet, the enzyme system for decreasing methaemoglobin to oxyhaemoglobin is not well developed in children under six months of age and this can lead to the occurrence of methaemoglobinaemia (WHO, 2006). This issue may also occur in adults who have genetically impaired enzyme systems for metabolizing methaemoglobin. The WHO maximum limit for nitrate is 10mg/L (WHO, 2011)

Fluoride

Fluoride exists both naturally and artificially. Its concentration in natural groundwater relies upon geological features, rock porosity level, temperature of the soil, depth of well, and physical and chemical features of water (Li, Gao, & Wang, 2014). Although both surface and groundwater have high Fluoride concentrations in a specific locality, the amount often happens to be lesser in surface water than in groundwater. Groundwater obtains its fluoride when the water infiltrates through rocks with fluoride-rich compounds.

Introduction of fluoride into the Densu River by anthropogenic activities may range from bricks making factories, tiles making factories and ceramic factories. As indicated by WHO (1984), these activities by humans are important sources of fluoride. According to WHO (2000), it is noted that the concentration of fluoride in coal and mud that is involved in producing bricks and tiles may go beyond 10,000 mg/kg, and this is believed to have introduced high amount of fluoride in the atmosphere after firing. It was indicated in a study by Swarup and Dwivedi (2002) that in China, more than 28 industries release fumes and effluents that are rich in fluoride into the environment.

The maximum contaminant level for fluoride is 4 mg/L, but since it has the potential for dental fluorosis, i.e., discolored or mottled teeth, it has ushered WHO to set a secondary standard of 1.5 mg/L (WHO, 2011). A higher level of fluoride is known to cause bone disease whilst lower levels of fluoride helps to avoid cavities in the teeth.

Hardness

Water is termed as hard when it does not lather well with soap. Hardness in water is determined by summing up the amount of calcium and magnesium in the water (American Public Health Association [APHA], 1998). Hard water has high content of minerals in it. According to Ameyibor and Wiredu (1991), hard water contains a high amount of Ca^{2+} ions and Mg^{2+} ions. Generally, hard water has no health effects on humans but can pose dangerous problems in an industrial environment (Acton, 2013). The maximum limit that is set by the WHO is 500mg/L (WHO, 2011)

Definitions of Urbanization

Different types and forms of definitions exist on what urbanization is. Even in the United Nations, their statistics on rural and urban populations depend on definitions of the terms ‘urban’ and ‘rural’ and this vary between countries. Almost one-quarter of countries rely only on standards linked to population size, these population standards themselves vary considerably.

It is generally known that urbanization comprises the shift in population from the rural setting to urban setting. From a demographic view, the urbanization level is best determined by the urban population share with the urbanization rate being the rates at which that share is increasing. It becomes even more confusing when urbanization is used to refer to the expansion of urban land cover (Montgomery & Balk, 2011). However, this definition will be applied to the urbanization situation found within the catchment of the Densu basin.

It has been a difficult task for researchers to arrive on an international agreement on how to define the boundaries of urban areas or determine when a settlement should be termed as urban. Some scholars rely on a simple and standardized definition which is based on population size and density and some countries have adopted that definition. Notwithstanding, the definition varies between regions and cities (Long, 1998). As indicated by both the World Bank (2009) and Cohen (2004), there exists no common definition because different countries and states have adapted their own factors for defining urbanization.

In many countries with Ghana being no exception, settlements termed as urban are expected to run specific administrative responsibilities. Such responsibilities are often conferred on the existence of physical features alone (Montgomery & Balk, 2011). On the other hand, other countries have many criteria which include administrative level, density and size and sometimes urban employment is considered.

In most countries and states with size criteria, the minimum population size is between 1,000 and 5,000. In Sweden for example, an area is termed as urban if its settlement consist of at least 200 households and have gaps of no more than 200 meters between them (Montgomery & Balk, 2011). In Ghana, with regards to demography, an area is termed as urban when the population is estimated as 5,000 and more. In Mali, a cut-off of 5,000 was used during the 1987 census, 30,000 in the 1998 whilst a cut-off of 40,000 was used in the 2009 census (Uchida & Nelson 2010; World Bank 2009). In places like Botswana, a place is termed as urban if it has a population of 5,000 or more and with 75% of economic activities being non-agricultural. According to the United Nations, a locality qualifies to be called an urban area if it has streetlights, sanitation, pipe-borne water, hospitals and schools (United Nations, 2001).

Effects of Urbanization (anthropogenic activities) on Water Quality

Access of surface water systems by people and livestock appear to be common in developing countries, especially in rural places where majority of its people lack access to portable water. This aids them to get water for their day-to-day needs from surface water systems that are often contaminated (Obi, Potgieter, & Matsaung, 2002). They frequently visit nearby rivers and streams especially during dry seasons when other water sources such as rainwater, groundwater and pipe-borne water are inaccessible. Human activities that result in the contamination of water bodies include watering of farmlands, bathing or swimming, disposing of waste and washing of clothes and vehicles (Yillia, Kreuzinger, & Mathooko, 2001). Since these human activities take place regularly within and beside water courses, they are major sources of pollution and are therefore collectively called in-stream activities. The faecal contents that are introduced into the water body as a result of these activities may influence microbial water quality (Zamxaka, Pironcheva, & Muyima, 2004). Unsanitary means of dumping faecal droppings from livestock and human waste are ways of introducing faecal matter into water systems. Faecal matter reduces water quality since nutrients, pathogens and organic matters are mostly present in them (Vinneraset, Holmqvist, Bagge, Albihn, & Jonsson 2003).

Degraded quality of water often leads to an increase in cost of drinking water treatment and also lessens opportunities for recreation and aquaculture (Ebdon, Muniesa, & Taylor 2007). Consequently, pollution from urban activities may present significant contamination to a river body. (Byamukama, Mach, Kansiime, Manafi, & Farnleitner 2005) The level of contamination of a water body often depends significantly on the origin and rate of contamination (Scott, Rose, Jenkins, Farrah & Lukasik, 2002) and so for instance, communities close to the Densu River are likely to cause high pollution than those further away.

To minimize contamination, it is very essential that regular monitoring of indicator parameters in water systems is undertaken (Shah et al., 2007). Such monitoring is required not only to assess health risks, but also to identify the necessary actions that may be required to solve the problem (Ahmed et al., 2007).

Water systems often attract urbanization as a result of the numerous resources they provide. These resource advantages make room for population and settlement increase along water systems. According to Shah et al. (2007), some anthropogenic activities that are likely to deplete the quality of water systems as a result of urbanization stem from industrial sources such as metal processing, textile manufacturers, food processing plant, steel production, sewage treatment plants and chemical manufacturers. Also, agricultural sources may include crop production, pastures, rangeland, feedlots and deforestation. All these forms of human activities manifest within and around the catchment of river Densu.

Many of these anthropogenic activities are taking place along the Densu River as a result of high urbanization and these have impacted negatively on the quality of the water hence further contributing to high levels of contamination of the water reservoir (Weija reservoir). This has eventually degraded the quality of the lake water leading to the high amount of treatment cost by the Weija Water Company, and also greatly diminishing the economically significant fisheries resources within the lake.

Urban Drainage System (Urban River)

According to Findlay and Taylor (2006), an urban stream can be referred to as a stream with an important section of its catchment consisting of developments where the combination of area roads, paved surfaces and roofs result in an impervious surface area. Population growth and the mass movement of population from rural to urban centers are resulting in rapid urbanization in most parts of the world (Goonetilleke, Thomas, Ginn, & Gilbert, 2005). It is important that this continual urban growth is astutely managed and subsequently, innovative measures adopted to ensure the protection of vital environmental values and places in an area.

Urban rivers are valued greatly as environmental, aesthetic and recreational assets. They may support floodplains and riparian zones that become local biodiversity hotspots or refuges, providing corridors for an otherwise isolated flora and fauna population and their habitat. Findlay and Taylor (2006) also attested to the fact that urban rivers may also provide benefits such as water supply, flood mitigation and disposal of waste water just as the Densu River provides.

Urban rivers are often heavily degraded due to the increased rate, volume and movement of pollutants into waterways from runoffs and from impervious surfaces (Goonetilleke et al., 2005). The resultant effect of these acts is the deterioration in water quality, degradation of river habitats and flash flooding. Walsh et al. (2005) termed and described the consistently observed ecological degradation of stream/river draining urban lands as 'urban stream/river syndrome'. The symptoms of the urban stream syndrome fall under four broad categories: stream/river hydrology, stream/river geomorphology, water quality and ecology and biodiversity. Descriptions of the hydrological and water quality impacts are found below.

Water Quality of Urban Rivers

The water quality of an urban river is highly variable and is an important measure of overall river condition (Findlay & Taylor, 2006). Walsh et al. (2005) specified that changes to the hydrologic regimes of urban places can affect water quality as the increased runoff velocities would result in erosion as well as the entrainment and transport of pollutants present on the catchment surface. Surface runoff, which is generally referred to as storm water, during its movement transports a variety of materials which are composed of chemical and biological origins to the nearest receiving water body. According to Goonetilleke et al. (2005), these contaminants can cause toxicity to aquatic organisms and alter ecosystem processes (such as nutrient cycling). The resultant effect would be the creation of a water body that is primarily modified from its natural state.

Pollutants in Urban Runoff

The main pollutants in urban runoff are litters, sediments and suspended solids, nutrients, heavy metals, hydro carbons, organic carbons and elevated water temperatures.

Sediments, Suspended solids and Nutrients

Papers, plastics, glasses, cigarette butts are forms of litters usually found in water bodies. Litter impacts on the visual amenity of the waterways, as it tends to float on the surface. It can also degrade habitat for aquatic biota and clog the drainage system impeding the flow of storm water. Some litters contain volatile solids that may be toxic to some organisms.

Suspended solids in urban areas are transported from streets and paved areas, rooftops, construction sites and other areas into water bodies when it rains and runoff takes place. Loads are generally 10 – 100 times greater in urban runoff than from undisturbed land and can be transported and deposited at any time as flow velocities decrease. There are both chemical and physical impacts associated with sediments that are transported into rivers. Chemical impacts relate to the transportation of pollutants - such as pathogens and nutrients - which gets attached to the sediments. The physical impacts include siltation and smothering of ecosystems, which reduce water clarity and block sunlight. Erosion from waste rock piles that are created by mining activities at the upper section of the basin of river Densu often increases the sediments load of the water after runoff.

Sedimentation may modify stream or river morphology by disrupting a channel or tributary, diverting tributary flows, and changing the bank or slope stability of a river course. According to Johnson, Swanston, and McGee (1971), these disorders can considerably affect the characteristics of sediments of a stream or river, thereby reducing water quality. The increase in sediments concentration in rivers retard processes of photosynthesis since high sedimentation increase the turbidity of natural waters, reducing light availability (Ripley, Redmann, & Crowder, 1996).

Urban rivers, according to Walsh et al. (2005), show higher nutrient concentrations and less efficient nutrients uptake rates. These cause eutrophication and aquatic growth stimulated by nutrients entering the water, which can alter the visual appearance of the water, lowering its beneficial value.

Visual impacts may include floating matter (algal blooms) and slimes. Other impacts can include dissolved oxygen depletion and objectionable taste and odour from algal blooms. When runoff, caused either by the melting of snow, rainfall or glaciers flow along the ground of an urbanized area where many human activities take place, the remnants which fall into river bodies usually introduce nutrients such as phosphates, nitrates, nitrites and sulphate.

Heavy Metals

Storm water runoff from urban areas (including roads, roofs, and industrial sites) contains significant loads of heavy metals. Pollution of rivers by heavy metals is caused when such metals as cadmium, arsenic, lead, copper, cobalt, copper and silver contained in exposed rock as a results of activities of underground mine come in contact with water. Such metals are of much concern because they are often leached out and moved downstream as water washes over the rock surface.

Lead and Copper

The high rate of weathering and leaching of lead and copper from waste rock dumps from the upper section of the river Densu leaves remnants of lead and copper in the water body (Ashanti Gold Company [AGC], 2001). The improper disposal of lead-acid batteries and copper wire at fitting shops that are found within the catchment areas of the river basin also accounts for high levels of lead and copper in the river. Soluble copper elements constitute a serious threat to human survival. Usually through agriculture activities, the environment is often injected with water-soluble copper compounds. Lead is a neurotoxin metal which is known to have a negative effect on the central nervous system of humans.

According to Rodricks (1992), children that consume water with high levels of lead content have low IQs. He also emphasized that there exists many publications that indicate a relationship between the decline in IQs of children and their long-term exposure to high concentrations of copper.

Iron

The weathering of the rock systems of the upper section of the river basin results in high concentration of iron in the water body. Some other sources of iron in the study area include the seasonal discharge of mining waste and acid mine drainage which consequentially increase iron levels in the surface water. Iron happens to be one of the major constituents in the lithosphere soil as oxides or hydroxides.

The level of toxicity of iron is governed by absorption or in-take. That is, the more one takes in the more one stays at risk. Cells of the intestinal mucous membrane absorb iron in the ferrous state. Many health problems exist that are as a result of consuming water of high amounts of iron, these include: hypothermia, anorexia, oliguria, metabolic acidosis and diarrhea.

Hydrocarbons

Hydrocarbons can enter storm water from vehicle wear, emissions and chemical spills. They can be direct toxic to aquatic organisms, and bioaccumulation through the food chain. Hydrocarbons can also cause oil slicks on the surface of the water, thereby degrading the visual amenity of the waterway.

Hydrocarbons in urbanized areas are often derived from industrial and commercial activities within the urban area that uses petroleum as a component of productivity input. Runoffs after heavy rains often usher these hydrocarbons into a nearby water body.

Hydrocarbons in water often kill finfish and shellfish by its smothering actions. Organisms such as fish in water bodies may find their nutrition being interfered by ingested hydrocarbon elements. In a shallow water body, contamination may persist for years (Chima, 2013). The presence of hydrocarbons on the surfaces of water may limit gaseous exchange, entangle and kill surface organisms and coat the gills of fishes.

Akani, Braide, & Amadi (2008) observed during their studies that when activities that involve the usage of oil or petroleum occur on land, such as the Ejamah-Ebubu incident near Eleme, rivers that were around the area in the 1970's became unclean for both domestic usage and aquatic living. With farmlands and swamps being heavily impacted, soils present too were no longer fit for farming.

Pathogens

Pathogens are a form of bacterial in a water body. Bacterial is a worldwide health hazard with many risk factors. Pathogens in water can occur in all types of water sources and their existence is particularly extensive in areas with greater amounts of untreated wastewater.

A wastewater is any water that has been used for purposes such as domestic or industrial and contains waste products. Such waste products can be chemical, biological or radioactive and are most often liquid or solids in nature.

Pathogens are sourced from animal faeces and sewage overflows which are produced through human activities. They are vectors of diseases which can reduce the recreational and aesthetic amenity of the receiving water body. A certain amount of nutrients is actually helpful in the growth process of aquatic plants, but too much of such nutrients tend to promote the growth of algae. The excessive growth of algae on water surfaces prevents sunlight from penetrating into the water and hence causing the destruction of important organisms, plants and the death of animals.

Temperature

Streams that accept water from conventionally drained urban areas often have high water temperatures, most likely due to heating by impervious surfaces and main piped pathways for water to the streams. Warmer water can inspire physiological processes in streams and create more problems of nuisance algal growth. Other streams adapted to cooler temperatures may suffer thermal stress (Walsh et al., 2005).

Reservoirs

Reservoirs are large artificial or natural lakes that are used to supply water for purposes such as drinking and irrigation. Reservoirs can be on-stream, that is when it is created in a river valley through the construction of a dam, or off-stream, which is made by making an excavation in the ground or by orthodox construction methods. Reservoirs are made to store water mainly during the wet periods in order to provide catchment demands all year round.

Water quality in reservoirs is determined by many factors such as the frequency, magnitude, duration, seasonality and quality of inflows and actions of in-lake processes. According to Wakawa, Uzairu, Kagbu, and Balarabe (2008), river water that flows or is pumped into reservoirs transport substances like nutrients, sediments and other contaminants, which may then be affected by in-lake processes such as settling of biochemical processes and suspended solids. Most as times, reservoirs that harvest and store water for potable drinking water supplies are best situated in forested catchments which are protected and where rural and urban activities are much restricted or banned. The major reason for restricting urban activities is to maximize the water quality of inflows and also to reduce the risk of contaminants. Bushfire runoff presents the highest risk of contaminant loads in these catchments. Other reservoirs that are mainly meant for irrigation require a lesser quality of water and may have therefore increased levels of development in the catchment.

Algal bloom is one of the major water quality issues within reservoirs. Many types of algal blooms exist, including toxic blue-green algal species (or cyanobacteria). The presence of algal blooms in water affect water amenity, making it unsuitable for potable supply, stock watering and recreation. They can also spoil water treatment processes. Increased light, temperature and nutrient concentrations are the primary factors responsible for high concentrations of algal blooms in water.

Remote Sensing (RS) and Geographic Information System (GIS)

Land use/ land cover maps are essential tools in natural resource planning and environmental management (Ehlers & Wenzhong 1996). Human activities have led to fast and large changes in land cover, which in turn have a negative impact on the environment as a whole. As a result, land cover is one of the most important elements for the assessment of the environment. Chaudhary (2003) argues that land cover is the basic geographic feature serving as a reference base for other environmental applications.

RS and GIS offers a cost – effective means to assess ecological features and to occasionally bring up-to-date baseline data regarding resource abundance and distribution (Sample, 1994). However, Green (1994) indicates that there exist many applications that indicate that remote sensing methods have much success in relation to the difficulty of interpretation of certain ecosystem characteristics. It is believed by many scientists that terrestrial vegetation has the most exclusive spectral reflectance features and its mapping has been among the mostly used and also well-built remote sensing applications (Valentine, Knecht, & MIller, 1998). GIS has been known to be a flexible and prevailing application tool for environmental resources inventory.

GIS technologies have the possibilities of demonstrating significant roles in all levels of monitoring programs (Franklin, 1994). The GIS multi-criteria abilities have been applied to measure and combine numerous environmental factors and scientific issues which gives directives in the selection of sites for observing and checking.

Producing Land Use Land Cover Change Maps

The first step in attempting to produce land use/land cover and change maps is the acquisition of satellite imageries. In this study, the Landsat 5 images were used. The Landsat 5 carries both thematic mapper ™ sensors and multispectral scanner (MSS). The thematic mapper ™ is an advanced earth resources sensor which is built to attain higher image resolution, good geometric fidelity, sharper spectral separation and better radiometric accuracy and resolution than the Multispectral scanner. These sensor images have a swath 185 km (115 miles) wide but each pixel in a TM scene represents a 30x 30 m ground area (except in the case of the far-infrared band 6 which uses a larger 120 x 120 m pixel). The Thematic Mapper sensor has 7 bands that concurrently record emitted radiation from the earth's surface. Before classifying acquired data, a selection of the available spectral bands may be made. According to Richards (1986), justifications for not using all existing bands (all seven bands of Landsat TM) rely in the problem of band correlation and occasionally, in the limitation of software and hardware.

The next step after the acquisition of the images is to geo-reference them. This is a process of relating images to specific map projections. Lillesand, Kiefer and Dupman (2004) concede that geometric transformation happens to be the simplest way to link an image to a map projection. A geometric transformation is a task that relates the coordinates of two systems. The process of geo-referencing involves two steps, which are selection of the suitable type of transformation and determination of the transformation factors. The type of transformation depends primarily on the sensor platform system used. Successful geo-referencing leads to the classification for the geo-referenced thematic images.

Image classification is the process of assigning pixels to nominal, that is, thematic, classes (Lillesland et al., 2004). Image classification serves a specific goal: converting image data into thematic data. In the application context, one is rather interested in the thematic features of an area (pixel) rather than its reflection values. Thematic features such as land cover, land use and mineral type can be involved in further analysis and input into models. Also, image classification can also be referred to as a reduction in data: the 7 multi-spectral bands could result in a single band raster file. Several land use/land cover (LULC) classification systems have been designed. These are the ITC LULC classification approach, the CORINW land cover classification system, the land cover classification system of the FAO and the USGS classification system.

The USGS hierarchical system considers the characteristics of several existing classification systems that are agreeable to data derived from remote sensors, including photography and imagery from satellites and high attitude aircraft (Avery & Berlin, 1985). The system attempts to meet the need for current overview assessments of land use/cover on a basis that is even in categorization at the first and second levels of detail. It is deliberately left open-ended so that various levels of users may have the ease in developing more detailed classifications at the third and fourth levels. This approach allows various users to meet their particular needs for land - resource management and planning and at the same time stay in line with the national system. The types of land use/cover categorization developed in the USGS classification system can be related to systems for classification of land capability and vulnerability to certain management practices, potential for any particular activity, or land value, either intrinsic or speculative, hence its application in this study.

Supervised Image Classification

One of the core stages in image classification is the "partitioning" of the feature space. Feature space connotes the mathematical description of the combinations of observations of a multispectral or multiband image. In supervised classification, this is attained by an operator who describes the spectral features of the classes by identifying sample regions. Supervised classification requires that the operator had to know where to locate the classes of interest in the area covered by the image. Such information can be obtained from dedicated field of observation or from general area knowledge or from dedicated field of observations.

Unsupervised Image Classification

Supervised classification requires knowledge of the area under investigation. If this knowledge does not sufficiently exist or the classes of interest are not yet well-defined, then an unsupervised classification can be applied (Lillesand et al., 2004). In an unsupervised classification, clustering algorithms are applied to partition the feature space into a number of clusters. Many approaches of unsupervised classification exist, their main drive being to produce spectral groupings based on certain spectral similarities (Burrough, 1986). With reference to the most common approach, the operator has to define the maximum number of clusters in a data set. In relation to this, the computer detects arbitrary main vectors as the center points to the clusters. Every pixel is then given to a cluster by the 'minimum distance to cluster centroid decision rule'. As soon as all the pixels have been labeled, further calculation of the cluster center is done and then labeled accordingly. The iteration stops when the cluster centers do not change anymore. In every iteration however, clusters which have less than a specific number of pixels are removed. Once the clustering is completed, analysis of the closeness and separation of the clusters begins by means of inter-cluster distances or divergence methods.

Merging of clusters needs to be done to decrease the number of unnecessary subdivisions in the data set. This could be done using a pre-specified threshold value. The operated is expected to state the maximum number of clusters/classes, the distance between two cluster centers, the radius of a cluster, and the minimum number of pixels as a threshold number for cluster elimination. Analysis of these cluster compactness around its center point is done by means of user - defined standard deviation for each spectral band (Richards, 1986). If a cluster is elongated, separation of the cluster will be done perpendicular to the spectral axis of elongation. Analysis of closeness of the cluster is carried out by measuring the distance between the two cluster centers. If the distance between the two cluster centers is less than the pre-specified threshold, merging of the clusters takes place. The derived cluster statistics are latter on used to organize the complete image using a carefully chosen classification algorithm (similar to the supervised approach).

When the definition of the training sample sets is done, classification of the image can then be carried out with the application of classification algorithms. There are many classification algorithms. Choosing an algorithm depends on the purpose of the classification and the characteristics of the image and training data (Robinove, 1986). The operator needs to decide if a ‘reject’ or ‘unknown’ class is allowed. Three classifier algorithms can be distinguished. First the box classifier is explained for its simplicity to help in the understanding of the principle. In practice, the box classifier is hardly ever used (Lillesand et al., 2004); the minimum distance to mean and the maximum likelihood classifier are normally used.

Land Use Land Cover Change Detection

Change detection happens to be an increasingly common application of remote sensed data. It is the process of detecting transformations in the state of a phenomenon through observations at different times (Turner, Moss, & Skole, 1994). Change detection is regarded as an essential exercise in monitoring and managing both artificial and natural resources. This is because it offers quantitative analysis of the spatial distribution of the population of interest. It usefulness cut across monitoring shifting cultivation, deforestation assessment, land use change analysis, crop stress detection, damage assessment as well as other environmental changes (Mumby, Gray, Gibson, & Raines 1995). Macleod (1998) made mention of four aspects of change detection which need to be considered when monitoring natural resources; namely detecting the occurrence of change; measuring the area extent of change; identifying the nature of the change and assessing the spatial pattern of the change.

Evidence by Singh (1989) has revealed that digital means of detecting change detection is a difficult task to be carried out accurately and unfortunately, many of the studies concerned with relative assessment of these applications have not sustained their deductions by quantitative analysis. Almost all change detections that are than digitally are affected by spectral, temporal, thematic and spatial limitations (Green, 1994). He further argues that the type of method employed can intensely affect the quantitative and qualitative estimations of the change. Within the same environment, different approaches applied may produce different change maps. It is therefore very important to be more careful when selecting a method or an approach. At the end not all noticeable changes will have equal important to the operator.

Conceptual Model for the Study

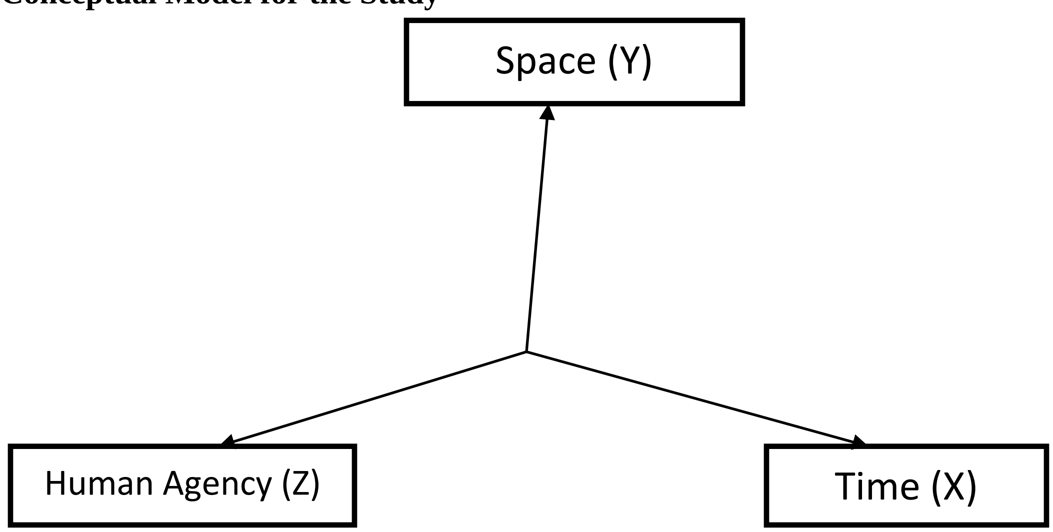


Figure 1: Three dimensional model for Land Use/Land Cover change analysis
Source: Adopted from Agarwal et al, 2001

Two separate and vital attributes must always be considered if land use/land cover changes are to be understood properly and these are the model complexity and model scale. According to Ehlers and Wenzhong (1996), real world processes function at diverse scales. Time step and duration are often discussed whenever temporal scales of models are considered. Time step is considered to be the smallest unit of analysis for change to take place for a specific process in a model. For instance, in this study, there is a probability that the water quality parameters may change seasonally. Duration in this study denotes the time frame the model is applied, which in this research is 2002 to 2016.

Spatial scale of a model relate to the aerial extent as well as the resolution of the study area (United State Department of Commerce [USDC], 1996). Resolution happens to be the tiniest geographic element of analysis for the model and example is the size of a cell in a raster system. In this study, a Landsat Thematic Mapper images with a 30m x 30m resolution will be used and also the extent which defines the total geographic region to which the model is applied is 924km^2

Two components as proposed by Agarwal et al. (2001) could be used to express scales of human decision making; these are domain and agent, and he related these to time and space. Agent denotes human player(s) in the model who are initiating decisions and effect. As the agent seizures the concept of who initiates decisions, the domain defines the exact institutional and geographic environment in which the agent operates. According to Lillesand et al. (2004), symbolization of the domain can be expressed in a geographically explicit model by using GIS layers or border maps. In relation to this research work, the agents are the individual human beings in the communities within the river Densu basin and the domain refers to the basin of the river.

Theories

Sustainable Development and Common Property Management

The Bruntland Commission in the year 1987 defined sustainable development in the report it published entitled, *Our Common Future.* The definition was in an attempt to relate issues of environmental stability and economic development. With regards to this, sustainable development was defined as “the ability to make development sustainable that target to meets the needs of the present without compromising the ability of future generations to meet their own needs” (The Johannesburg Declaration on Sustainable Development, 2002). Although there exist many definitions, that of the Bruntland Commission is accepted as the most often used definition of sustainable development (Cerin, 2006).

This concept of sustainable development has its overall goal of ensuring stability of the environment and economy for a long-term period (Stoddart, 2011). Its motives tend to provide a framework that integrates developmental strategies and environmental policies (The Johannesburg Declaration on Sustainable Development, 2002).Though the meaning given to sustainable development in 1987 was quite comprehensive, the 2002 World Summit on Sustainable Development gave a broader perspective to the standard definition. Three broadly applied pillars of sustainable development were highlighted, namely social, environmental and economic. The Johannesburg Declaration focused on an all-inclusive responsibility to strengthen and promote the inter-dependency of such pillars; thereby ensuring sustained social development, sustained environmental protection and sustained economic development at local, national, regional as well as global levels (The Johannesburg Declaration on Sustainable Development, 2002).

It could be well noted that this aim of ensuring sustainable development of resources could be achieved only if the 'Common Property Management Theory' is noted and enforced. This theory is of the view that a common positive notion given to a resource by a group of subjects would always ensure its continuous existence and maintain its importance. In other words, the acceptance by all members of a community or an area of the importance of a resource calls for a collective protection. As indicated by Smith (1981), the collective treatment given to a common property ensures its continuous existence and importance. This dissertation takes into consideration these two theories since when joined together; both would ensure a better integration of social, environmental and economic developments. Pollution of water of the Densu River and the Weija Reservoir is a clear indication of sustainable development failure. Porter and Claas (1999) theorized that polluting an environmental resource is a sign of inefficient resource use.

Ensuring clean water sustenance at the Weija Reservoir requires an integrated social, environmental and economic development on an equity basis.

Therefore, win-win opportunities for the economy and environment can be attained through collective societal improvements in friendly activities with the environment such as reducing pollution in production processes (Porter & Claas, 1999).

CHAPTER THREE

THE STUDY AREA AND RESEARCH METHODOLOGY

Introduction

This chapter consists of and discusses the study design, study area, sources of data and data types as well as the processes involved in trend detection, image processing, image classification, change detection and analysis.

Study Design

The descriptive study design was adopted with the aim of establishing a relationship between urbanization and the quality of raw water of the Weija reservoir. A descriptive design is applied in a study to describe what is prevalent with respect to the issue or problem under study (Sarantakos, 2005). It is believed that descriptive survey method gives a better source of primary data collection in the Social Sciences.

Its application permits the usage of both quantitative and qualitative methods to observe, describe, record, analyse, and interpret situations that exist and also to discover relationships existing between two or more variables. The study employed quantitative research methods where already existing data from the Weija Head Works was analysed. Again, interview schedule (close-ended and open-ended) were used to collect first hand data to provide a comprehensive resource of data from the respondents. This research design helped in structuring the study in a way which facilitated the answering of questions such as where, what, when, and the relationship between urbanization and the quality of raw water of the Weija Reservoir.

Study Area

Location and Description

River Densu is 116 km long and its source of water is from the Atewa-Atwiredu mountain range which is in the eastern region of Ghana. Its mouth is the Weija Reservoir which is located about 17km west of Accra. In 1977, the Weija Reservoir (0º 20' W 0 º 25' W and 5 º 30' N 5 º 45' N) was created through damming of River Densu by the Ghana Water Company Limited (GWCL) to replace the earlier one which was eroded in 1968. It was created mainly to provide potable water. The Weija Reservoir serves as a water provision system for the western parts of Accra and also for irrigation projects.

According to Vanden, and Bernacsek (1990), the Weija Reservoir is 2.2 km wide, 14 km long, with a mean depth of 5 m and a total surface area of 38 km^2. Its surface elevation is estimated to be 14.37 (Nukunya & Boateng, 1979).

Map of the Study Area

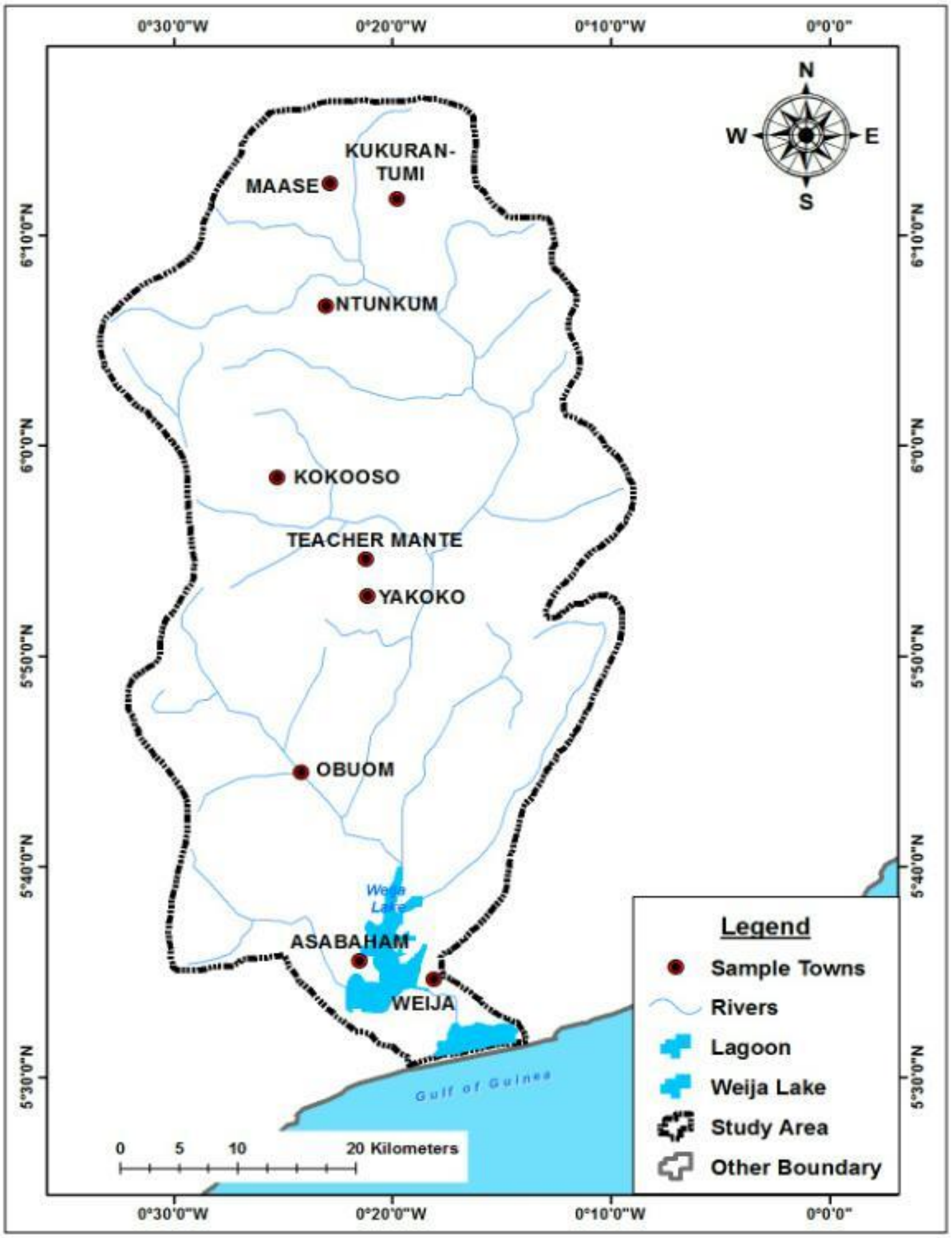


Figure 2: River Densu showing communities and the Weija reservoir

Source: Department of Geography & Regional Planning, University of Cape Coast, 2015

Climate and Vegetation

Climatic conditions of the area are more tropical in nature with an average temperature of 27^{o}C. The river's catchment lies in the coastal savanna zone where rainfall is often seasonal with an average of 65.5mm. Anon indicated that the major and minor rainy seasons are from April to July and September to November whilst the dry season is from December to February (Anon, 1997). The average annual rainfall for the entire Densu River Basin ranges from 875mm in the south to 1125mm in the north. The vegetation comprises of coastal savannah, moist semi-deciduous forest in the north and thicket and grassland in the south.

Geology and Soil

Starting from the source of the river to where it meets the sea, the Densu River in its upper course moves over Birimian rocks such as schists, phylites, grey wackes and tuffs. In its middle course, it traverses on Birimian rocks such as granodiorites and granites whilst in the lower course, which the Weija Reservoir forms part of, it moves on 'Togo series' such as shale, quartzites and phyllites. Soils found in the course of the river are loamy savanna ochrosols which are mostly red or reddish brown in colour. These soils are well drained, porous and friable. Forest ochrosols with colours being brown or orange brown, red or reddish brown, with adequate amount of nutrient are found in the northern part of the river basin. According to Anon, about 96 percent of soils in the Densu basin are forest ochrosols with the remaining 4 percent being savannah ochrosols and savannah lithorols occupying the southern portion (Anon, 1997).

Topography and Drainage

The relief of an area has a significant influence on the movement of ground water as indicated by Domenico and Schwartz (1998). The DRB has three broad topographical divisions namely Akwapim Range, Eastern Plains and Western Lowland. The Western Lowland has a base level of about 67meters above sea level and it is characterized by low and rolling topography. It has steep low ridges in several places which ranges from 300 to 567 ml. These ridges consist of granite and gneiss in the west, and siltstone, shale and sandstone in the east. According to Ahmed et al., (1997), these ridges are usually parallel to the northeast trending regional structures, and generally have steep slopes in the west and gentle slopes in the east. The Akwapim Range is located in the middle of the Eastern Plains and Western Lowland and also parallel to the regional folds and faults. It moves northeast-southwest with its boundaries between 6.5 and 9.5km wide. It is made up of quartzite and rises from 30 to 567 ml with the western slopes being much steeper than that of the eastern slopes.

The DRB exhibit a dendritic drainage pattern and normally comprises a dissected landscape which is a few meters high along the coast to about 700m within the Akwapim Hills in the northeast. The river has about seven tributaries and these are the Kuia, Made, Nsakye, Dabro, Jei, Adeiso, and Suhyien (Anon, 1997).

Administrative Structure, Population and Settlement Pattern

There are three (3) regions and 13 district municipal and metropolitan assemblies found within the basin. Approximately, the northern portion covers about 72% of the basin and this lies within the Eastern Region, 23% found in the Greater Accra Region whilst the remaining 5% is found within the Central Region. Among the 13 administrative districts, about 85% of the basin area is covered by New Juabeng, Akwapim South, East Akim, Ga West and Suhum/Kraboa/Coaltar. The area covered by Yilo Krobo, Fanteakwa, Kwaebibirem districts which are located in the northern section of the basin constitute only about 1% of the basin area.

With reference to the data provided by Water Resources Commission (2007), using the year 2000 Census results, Table 1 shows the total population found within the Densu River Basin by the year 2000. From the table, settlement classifications were made for each district showing whether people live in rural or urban settings. Per Ghana's definition, an urban population consists of all settlements with populations more than 5,000.

Table 1: Population in the Densu River Basin (2000 Census)

Region	District	Settlement category	Population (2000)	Area in basin (km2) (%)		Density (pop/km2)
Eastern	Fantekwa	Rural	800	10	0.4	80
		Urban	0			
	YiloKrobo	Rural	1200	18	0.7	67
		Urban	0			
	East Akim	Rural	27500	334	12.8	223
		Urban	47000			
	Kwaebibirem	Rural	0	2	0.1	-
		Urban	0			
	New Juabeng	Rural	22000	209	8.0	651
		Urban	114100			
	Suhum/Kraboa/Coaltar	Rural	101700	763	29.3	174
		Urban	31000			
	Akwapim North	Rural	19700	146	5.6	169
		Urban	5000			
	Akwapim South	Rural	53100	322	12.4	298
		Urban	43000			
	West Akim	Rural	10500	88	3.4	212
		Urban	8200			
Greater Accra	Ga West	Rural	125500	546	21.0	854
		Urban	341100			
	Ga East	Rural	2300	10	0.4	870
		Urban	6400			
	Accra Metro	Rural	2100	30	1.2	927
		Urban	25700			
Central	Awutu/Efutu/Senya	Rural	8800	122	4.7	154
		Urban	10000			
Densu Basin, total		Rural	375200	2600	100	387
		Urban	631500			

Source: Water Resources Commission (2007)

Socio-Economic Profile of DRB

Agriculture is the key economic activity in the rural areas found within the basin and it has created employment for majority of the people. Aside agriculture, some socio-economic activities such as small scale gold mining, wholesale, retail and manufacturing also exist within the Densu River Basin.

Agriculture

Agriculture does not only serve as a key economic activity in the Densu catchment but it is also a way of life for those living within the catchment area. The main livestock reared within the Densu catchment are poultry, goats, sheep, cattle, pigs, grasscutters and rabbits. Crops grown include maize, cassava, groundnuts, pineapple and cowpea among others. Cash crops such as cashew, watermelon, millet and mango are also grown in the catchment of the river. Agricultural activities within the Densu catchment cannot be discussed without making reference to the commercial farming that goes on at Nsawam where majority of these farming activities takes place. Fishing is also another major agricultural activity that is undertaken along the course of the river. According to Asanti, Quarcoopome and Amevenku (2005), the dominant fish species that can be found in the Weija Reservoir include tilapia, guineensis, barbusmacrops, hemichromisfasciatus, cichlidae and cyprinidae.

Logging is another agricultural related activity that takes place within the basin and it principally occurs in the northern section of the basin. There are a number of timber concessions given to larger timber operators by the Forestry

Commission. Harvesting of wood for fuel has also become another key economic activity within the river Densu catchment and it takes place particularly in rural areas.

Small-Scale Gold Mining

Stone quarrying and small-scale gold mining activities are also common in some parts of the basin. Stone quarrying as well as sand winning activities are carried out especially in Nsawam, Koforidua and some other localities in the Ga district. On the other hand, the mining activities occur on the Birimian formation in the East Akim district.

Manufacturing, Wholesale and Retail Trading

At the urban centers, the economic activities are more varied and the significant ones include manufacturing, wholesale and retail trading. Industries in the basin include fruit processing, bottle water production industries, and auto servicing shops, saw milling, block making, metal work, and local soap manufacturing. There also exist large commercial shops and large markets where manufactured goods are sold and this bring people from rural and urban areas together for trading.

Table 2: Occupation (in %) of the Economically Active Population

Economic activity	Districts East Akim	New Juabeng	SuhumKraboa Coaltar	Adwapim North	Akwapim South	West Akim	AwutuEfutu Senya	Ga East/Westt	Accra Metro
Agriculture and forestry	5.7	15.9	59.9	50.1	46.9	59.8	36.8	13.9	3.7
Fishing	0.9	1.4	0.8	0.3	2.1	1.2	10.5	1.9	2.5
Mining and quarrying	1.1	0.7	0.4	0.5	1.4	1.2	0.9	1.9	1.4
Manufacturing	8.8	15.2	10.6	9.3	10.5	8.8	13.6	14.9	17.4
Wholesale and retail sale	11.5	28.6	13.4	16.7	17.1	13.6	16	27.2	33.9
Construction	2.6	6.0	1.7	3.0	2.7	1.4	4.4	10.1	5.5
Hotel and restaurant	2.8	4.0	2.8	2.9	3.5	2.7	2.4	3.5	4.6
Transport and communication	2.2	5.3	2.6	3.6	3.7	2.5	3.8	6.8	6.6
Education	4.3	6.8	3.1	4.9	4.2	3.0	3.7	8.0	8.0
Other unspecified activity	8.1	16.1	4.7	8.7	7.9	5.8	7.9	11.8	16.4
Total	100	100	100	100	100	100	100	100	100

Source: Water Resources Commission (2007)

Population

With regard to the interview survey, the study targeted communities that lie along the river course. It was believed that communities close to the river course would have much information and influence on the state of the water.

Targeted people for interviews were basically adults because only residents who were eighteen (18) years and above before the year, 2002 were involved. Majority of them were grown enough to have a lot of information about the quality of the water and changes that had taken place within the Densu catchment.

Sample Size and Sample Size Determination

The study involved nine (9) communities and these communities were sampled from the three courses of the river (upper course, middle course and lower course).

A Sample is a randomly selected group of entities or objects from a targeted population. Selection of such a number from the total population unit is such that the sample elements represent the total population. Two Hundred and Fourty-Six (246) respondents from the nine communities were interviewed during the study.

The researcher adopted the Fisher, Laing, Stoeckel and Townsend (1998) approach for determining sample size in this study. The formula for this approach is; $n = {}^2pq/d^2$; where: n= the desired sample size (when the population is greater than 10,000; population for this study was 53,861); z = standard score at 95 percent confidence (1.96); P is the estimated proportion of target population

(80%) q= 1.0-p; and d= degree of accuracy desired (0.05). After the substitution of these figures into the formula, the sample size for the study was derived at 246. Sample sizes for the various nine communities were derived proportionally and are found in Table 3.

Sampling Technique

The sampling techniques applied in selecting communities for the study were 'Purposive' and 'Simple random'. Purposive method is a non-probability technique whilst the Simple random method is a probability technique.

After 50 communities within 200 meters buffer zone of the river had been purposively sampled, they were later purposively grouped under the three courses of the river; that is the upper course, the middle course and the lower course. Communities within each river course were given numbers and with the application of the Simple Random Sampling Technique or the lottery method, first three numbers were chosen to represent each river course. So in all, nine communities were sampled.

The sampling techniques applied in choosing the respondents were purposive and accidental and these were all non - probability sampling techniques. Purposively, all the people who were 18 years or over before 2002 qualified to be interviewed. The respondents from the various communities were interviewed accidentally. This accidental technique was used because it was convenient and fast.

Table 3: Sample population of households (2010 population census)

Selected Communities	Total Population	Proportion Allocation of Sample Size (%)	Sample Size
Maase	4218	7.8	19
Kukrantumi	608	1.1	3
Ntunkum	3197	6	15
Kokooso	1032	2	6
Teacher Mante	500	1	3
Yakoko	3000	5.6	14
Asabaham	10811	20	49
Weija	15892	29.5	71
Obuom	14610	27	66
Total	53868	100	246

Estimations of Population Figures

Population figures were estimated from the year, 2000 population figures which were provided by the Densu River Authority, and the 2010 population figures which had to be calculated from the various districts, municipals and metropolitan assemblies' 2010 population data which was downloaded from the Ghana Statistical Service website. Population figures of communities within the basin were summed up on regional basis and using the regional population growth rate for 2000 and 2010, the various estimated population figures were calculated regionally.

Table 4: Population Figures and Growth Rates for the Years 2000 and 2010

REGIONS WITHIN THE CATCHMENT	2000 POPU	2010 POPU	2000 GROWTH RATE (%)	2010 GROWTH RATE (%)
Central	8800	16400	2.1	3.1
Greater Accra	503100	616307	4.4	3.1
Eastern	484800	547152	1.4	2.1
TOTAL	1006700	1179859	7.9	8.3

Source: Ghana Statistical Service (2012), Water Resource Commission (2007)

Estimation formulae

The formulae below together with its definitions were used to estimate population figures for 2002, 2007 and 2017. One of the shortcomings of this formula is that, it had no assumptions.

$$P = P_0 * e^{r\,t}$$

P = Total population after time‘t’

P_0 = Starting population

r = % rate of growth

t = Time in hours or years

e = Euler number = 2.71828

Source: www. Socratic.org

Sources and Types of Data

Both primary and secondary types of data were utilized in this study. Primary data consisted of data that were obtained from the field survey and an example of this is the community's perception of the state of the water. Three visits were made to the study site; the first was to get information from the upper section of the Densu River Basin, the second was to get information from the middle section of DRB and the last was to get information from the lower section of DRB.

The secondary data included data on water quality parameters which were all physio-chemical (phosphate, Nitrate, Ammonia, Turbidity, Colour, pH, Temperature, Sulphate, Iron, fluoride, Total solids, Suspended Solids, Total Dissolved Solids, total hardness, Calcium, and Manganese) from the Weija head works. Also, the population data from the year, 2000 census on the over two hundred communities that are situated within the Densu River Basin was obtained from the Ghana Statistical Service. Population figures for the year 2002, 2007 and 2016 were estimated by applying the regional population growth rate of 2000 and 2010. In addition, Google earth and satellite images of the study area were also used. Three clouds free Landsat imageries of the years 2002, 2007 and 2017 were downloaded from the United States' Geological Survey (USGS) website with no fee charged. The 2002 image was downloaded in February, the 2007 image was downloaded in January and the 2017 image was downloaded in January. For the purposes of selecting training samples and the validation of the classification results, Google earth was used.

Table 5: Satellite Data used for the Study

Satellite	Sensor	Path/Row	Spatial Resolution	Acquisition Date	Source
Landsat 7	ETM+	193/56	30m	02/2002	USGS
Landsat 7	ETM+	193/56	30m	01/2007	USGS
Landsat 8	OLI/TIRS	193/56	30m	01/2017	USGS

Source: United States Geological Survey (2017)

Data Collection Instrument

The study demanded that a structured interview schedule be developed to know what the communities gained from the water resource and the communities' perception of the state of the water. In order for the researcher to clarify issues to the respondents, he opted for an interview schedule. In an attempt to assess the state of the water, the respondents needed some technical explanations and this made it necessary for interview schedules to be used. An argument raised by Bluman (1998) makes it clear that interview surveys are commended with the ability to obtain information from individuals who do not have the ability to either read or write, and also guarantees the completeness of the interview. Assurance of in-depth responses to questions, and ensuring high response rate are some of the reasons behind the choice of interview survey for this study.

The instrument had four sections. The first section captured background information (socio-demographic characteristics) of respondents, the second section captured activities/benefits that communities derived from the basin while the third section captured issues on the quality of water and urbanization.

Producing Land Use- Land Cover Change Maps

Image Processing

The acquired satellite images were subjected to processing which involved radiometric and geometric corrections. Radiometric correction was performed on the Landsat images to remove atmospheric effects so as to improve the accuracy of image classification. Noise and haze were corrected for each band of the Landsat datasets during this procedure. Geometric corrections were also done so as to ensure that the geometric identities of the imagery were as close as possible to the real world. Geo-referencing the image formed part of the geometric correction procedures.

Geo-referencing was done to relate images to specific map projections. Geometric transformation was applied to link the images to map projections. A geometric transformation is a task that relates the coordinates of two systems. The process of geo-referencing involved two steps. The first is the selection of the suitable type of transformation and second is to determine the transformation parameters. Landsat images were originally in global coordinate system UTM zone 30/WGS 84. Successful geo-referencing led to the classification for the geo-referenced thematic images.

Image Classification

According to Lillesand, Kiefer, and Dupman (2004), the ultimate motive in classifying an image is to automatically categorize all pixels in an image into either land cover themes or classes. Image classification was therefore necessarily required to convert remotely sensed data into thematic data.

Thematic characteristics such as land cover/use were given consideration. With respect to image classification systems, the USGS classification system was applied. This system was applied because it has features of several prevailing classification systems that are open to data derived from remotely sensed imageries and photographs from satellites (Avery & Berlin, 1985). This system is left open-ended so as to allow various classes of users to have the ease in developing more enriched classifications at its third and fourth stages. Such a system with it usage allows all sorts of users to achieve their particular needs for planning and land - resource management and at the same time makes them remain well-matched with the national system, hence its application in this study. Both supervised and unsupervised classification algorithms were applied in this study.

The supervised classification process required that the researcher defines the spectral features of the classes through identification of sample areas (training areas). It also required the researcher's familiarity with the Area of Interest (AOI). Training samples were selected from high-resolution images that were obtained from Google Earth Images. According to Jensen (2005), this method is the most frequently used in remote sensing image data analysis and through this; one can identify and locate land cover types by a combination of fieldwork and previous personal experience.

Image classification used bands one (1), two (2), three (3), four (4), five (5) and seven (7) because according to Campbell (2002), they are responsive to the amount of land cover present in images. For the purpose of this study, band 2 was put in channel Blue, band 5 in channel Green and band 7 in channel Red for Landsat 7 ETM+ (Enhance Thematic Mapper plus) whilst band 3 was put in channel Blue, band 5 was put in channel Green and band 7 was put in channel Red for Landsat 8 OLI/TIRS (Operational Land Imager / Thermal Infrared Sensor). Classified images were filtered before producing the final output after classes had been selectively combined. Below is a figure summarizing land use/cover mapping procedure.

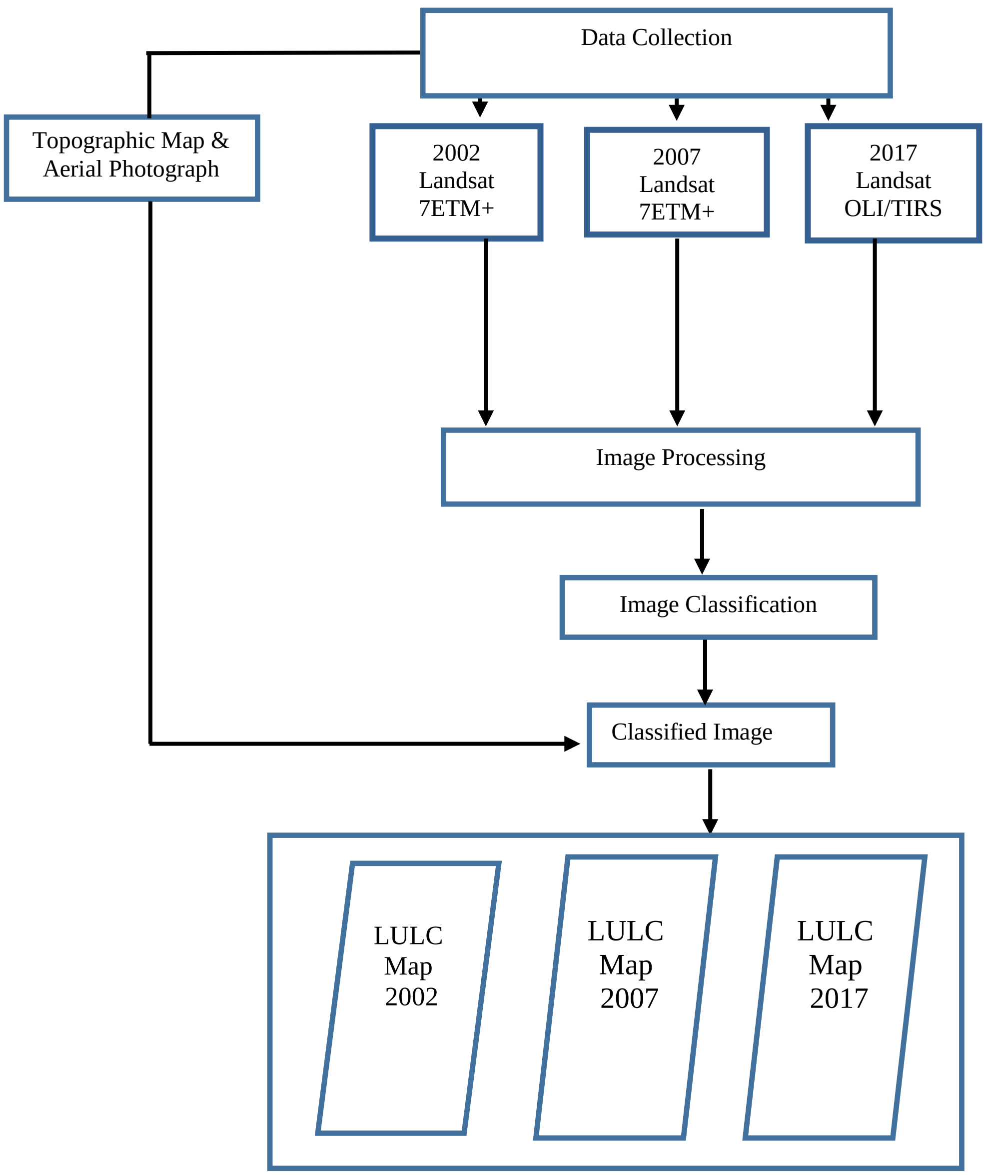


Figure 3: Summary of land use/cover mapping procedure
Source: Adapted From Murwira, (2000)

Land use/cover Change Detection

Many techniques exist in land use/cover change detection. Principal Component Analysis (PCA), Image differencing, Post classification comparison and Multi-dimensional temporal feature space analysis are some of such techniques. The post-classification comparison method, which involves an overlay of independently classified images, was employed to detect change in the form of location and extent. According to Chen (2002), it is the most commonly used quantitative technique of change detection. In post-classification technique, the change is detected from independently classified land use/cover classes of each of the dates under investigation. Respective Land use/cover maps were used to derive Land use/cover change maps for the periods 2002-2015. After going through post classification processes, both absolute and relative change of each land use/cover map was calculated using matrix dialogue in ERDAS Imagine 2013. This helped in the representation of changes within the years in the form of change map and change matrix table.

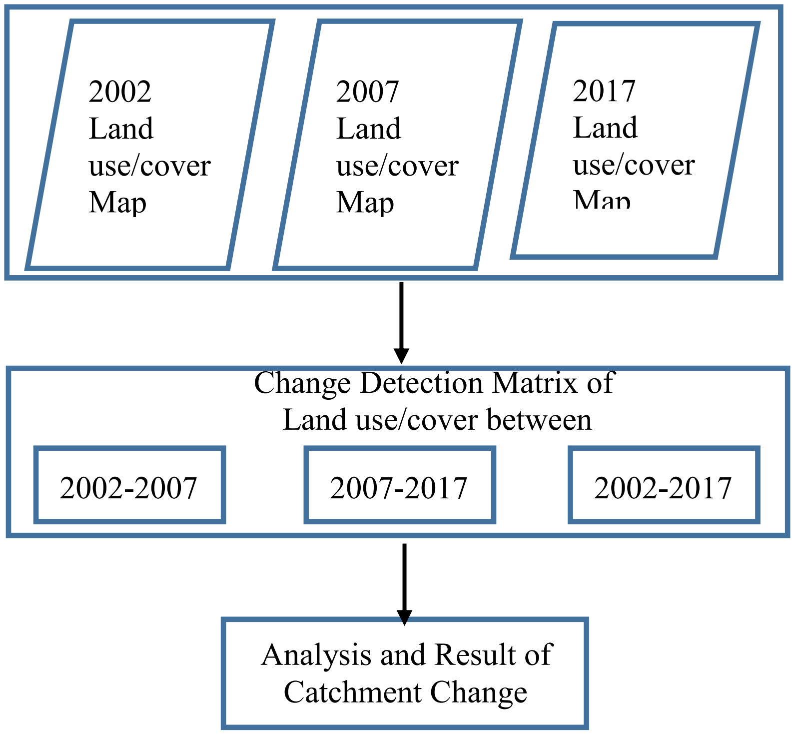


Figure 4: Summary of Land Use/Cover Dynamics Procedure

Source: Adapted From Murwira (2000)

Water Sample Preparation and Analysis (April and May)

For the sake of verifying the existing secondary data, it became important that the researcher takes water samples from the Weija reservoir and run some analysis. The samples were collected every two weeks in each month after which results from the analysis were compared to the recorded ones by Weija Head Works (WHW) in the respective months.

The researcher with the help of two field assistants collected water samples from the Weija Reservoir. The collected samples were submitted to the water research laboratory of The Council for Scientific and Industrial Research (CSRI). The samples were analyzed for Phosphate, Nitrate, Ammonia, Turbidity, Colour, Sulphate, Iron, Fluoride, Total Solids, Total Suspended Solids, Total Dissolved Solids, Total Hardness, Calcium and Magnesium.

Determining content of Total Solids, Total Suspended Solids and Total Dissolved Solids

Values for Total Solids, Total Suspended Solids and Total Dissolved Solids of the collected samples were determined by using Jennway Conductivity meter model 4520.

Determining Turbidity content

Turbidity values were taken using a cybercan IR TB 100 Turbidimeter. The turbidimeter was calibrated with 1000 NTU, 100 NTU, 10 NTU and 0.02 NTU calibrated guideline or standard. The colour of the samples was determined by colour comparator.

Determining pH

pH values of the samples were measured with a portable pH meter known as Horiba pH Multi-parameter.

Determining Iron content

Iron contents in the water samples were determined using atomic absorption spectro-photometer (AAS), AAS 220 model.

Determining Hardness content

For total hardness determination, a 100ml of the water sample was put into a 250ml conical flask and 10L amount of ammonium chloride buffer was added to the contents in the conical flask. Two (2) drops of Erichome Black T indicator was latter added. Titration was repeated several times until a consistent value was attained.

Determining calcium content

For calcium determination, 100ml of the water sample was put into a 250ml conical flask. An amount of 4 ml of sodium hydroxide solution was added to the mixture in the flask. Later, about 0.2g of murexide indicator was added. Content present in the flask was repeatedly titrated against 0.02M EDTA until a titre of consistency was obtained. Calcium Hardness was calculated as CaCO3 (mg/L) = Average Titre Value × 20.

Determining magnesium content

The differences between the values for Total hardness and Calcium hardness that were derived gave values for magnesium hardness.

Determining Fluoride content

Fluoride content was determined by using Wagtech Fluoride test kit. This test kit comprised Fluoride No.1 and No.2 tablets, Round Test Tube of 10ml glass and Wagtech photometer. The test tubes were later filled with the various water samples to a mark of 10ml on the tubes. This was followed by the breakdown of fluoride tablets, Fluoride No.1 tablet was broken and mixed to dissolve, followed by Fluoride No.2, which was also broken into pieces and mixed to dissolve in each of the water samples. The test tubes were later allowed to stand for about 5 minutes until full colour development was achieved. Readings from the photometer were recorded and compared with the Fluoride Calibration chart.

Determining Sulphate content

Sulphate content in the water sample was determined using the Wagtech sulphate test kit. The procedure was based on a single tablet reagent with Barium Chloride in a slightly acidic formulation. Water samples were situated in a tube to the 10ml mark of the glass. One sulphate tablet was crushed and stirred to dissolve in each sample. The presence of sulphate was indicated by a cloudy solution. Water samples were then made to stand for about 5 minutes and then stirred again to ensure uniformity. Later, readings from the photometer were taken and compared to the sulphate calibration chart.

Determining Phosphate content

For phosphate contents in the water samples to be determined, one drop of phenolphthalein indicator was placed in a 100 ml of the sample water. Later, acid content was added in drops until the water sample turned pink, after which 4 ml of molybdate reagent I and 10 drops of stannous chloride reagent I were added and stirred thoroughly. After 10 minutes, absorbance was read at a wavelength of 690 nm on the T60 UV spectrophotometer.

Determining Nitrate content

Determination of Nitrate was successfully done by applying the Hydrazine reduction method. Water sample of 10.0 ml was pipetted into a glass test tube and 1.0 ml of 1.3M NaOH was added and mixed gently, this was followed by 1.0 ml of reducing mixture which was also gently mixed. The mixture formed was heated for 10 minutes at 60°C in a water bath and was made to cool. An amount of 1.0 ml of colour developing reagent was later added to the mixture and shaken well. Using a T60 UV Visible Spectrophotometer, absorbance was read at 520 nm. The method detection limit was 0.005 mg/l.

Determining Temperature

Values for temperature were determined on site. Some amount of aliquot of 50 ml of sample was measured into a 100 ml beaker after which a Mercury-filled temperature cell was immersed in the solution and the readings that appeared on the thermometer were recorded.

Statistical Analysis

Interview schedules were taken through the coding processes and entered into Statistical Product and Service Solutions (SPSS) version 16 for analysis. Results were presented in tables and interpretations were done with the help of descriptive tools such as percentages.

Image pre-processing and supervised maximum classifications of land use/cover classes were carried out using the ERDAS imagine 2013. ArcGIS software version 10.1 was also used for data analysis, management, and making layout for final mapping.

Statistical analysis of the data on water quality parameters was done using Microsoft Excel. Descriptive summary statistics such as mean concentration as well as graphs were generated. The mean values were compared with the water quality criteria of the World Health Organization (WHO, 2011) and Ghana Standard Board Guideline Values, (GSA, 2015)

Ethical Issues

Some ethical issues were considered during the data collection process. First, an introductory letter was sent to the agencies in charge of the Densu River. The researcher sent introductory letters that were obtained from the Department of Geography and Regional Planning of the University of Cape Coast to the Ghana Water Company at Kanda, the Densu River Authority and the Weija Head Works seeking permission to collect existing data on water quality parameters and other primary data from some communities in the study area.

Also, the researcher had to seek the consent of respondents before soliciting information. Respondents were informed concerning the kind of questions they were to expect, the purpose of the information being sought and how the information would be handled. They were also assured of the confidentiality of their responses. It was after respondents had been informed of all the above were they willing to participate in the data collection process.

CHAPTER FOUR

LAND USE - LAND COVER

Introduction

This chapter presents analysis and discussions made on the results that were deduced from population occupants of Densu River Basin and satellite images for DRB. Issues discussed include population variations, state of the land use/cover types in 2002, 2007 and 2017 and changes in land use/cover types over the 14-year period. The chapter further presents the analysis of land transformation as well as depletion of land use/cover type.

Population figures estimations within the DRB

Table 6: Estimated Figures for 2002, 2007 and 2016

REGIONS WITHIN THE CATCHMENT	2000 POPU	2010 POPU	GROWTH RATE FOR 2000	GROWTH RATE FOR 2010	EXTD POPU FOR 2002	EXTD POPU FOR 2007	EXTD POPU FOR 2016
Central	8800	16400	2.1	3.1	9,169	10,093	19,405
Greater Accra	503100	616307	4.4	3.1	547,372	658,054	730,940
Eastern	484800	547152	1.4	2.1	498,374	532,310	616093
Total	1006700	1179859	7.9	8.3	1,054,915	1,200,457	1,366,483

Source: Ghana Statistical Service (2012), Water Resource Commission (2007)

The Table 6 above gives estimated population figures for the years 2002, 2007 and 2017. From the table, the number of people that were occupying the DRB was 1,054,915 as of 2002. Five years down the line, the population figure increased to 1,200,457 which indicate a percentage increase of 13.8. On the other hand, the population change between 2007 and 2016 was 166,026 which show a percentage increase of 13.83. On a yearly average, population increase in the DRB between 2002 and 2007 was 29,108 while the yearly increase in population between the years of 2007 to 2017 was 18,447. The population change between 2002 and 2016 was 311,368 which indicate a percentage increase of 29.53 and the average yearly population increase for the 14 years was 22,254.

The interpretation above gives a clear insight that the human population occupying the DRB has been increasing over the 14-year period and this contributes directly to the rate at which urbanization has been increasing. The increase in population on the DRB will definitely result in the expansion of land cover and this is regarded as urbanization according to Montgomery and Balk (2011).

Land Use/Cover (LULC) Classes of the River Densu Basin

The LULC mapping was based on the partition of the study area using the acquired remotely sensed data of 2002, 2007 and 2017. Five main LULC classes were considered using their spectral and textural characteristics and their feature space as explained in Table 7.

Table 7: Description of Land Use/Land Cover Units

Land cover/use	General description
Water	Water includes all areas within the landmass that persistently are water covered. Category includes stream, lakes, reservoirs, bays and estuaries.
Bare land	Land areas of dry and exposed soil surface as a result of both natural causes and human acts.
Farm land	Farm land represents all forms of land used normally for the production of food and fiber. This category includes groves, cropland and pasture, orchards, nurseries, vineyards, confined feeding operations, ornamental horticultural areas and other agricultural land.
Built-up	Built-up refers to places of intensive use with structures. This category include, residential areas, industrial areas, commercial areas and community service areas (playing grounds, parks, lorry parks)
Open forest	Forest lands that have a tree-crown aerial density (crown closure percentage) of 5 percent. It includes areas that show shrubs, sparsely located trees and patches of bare soil. Areas of isolated thicket and extensive grass cover are also classified under this category.
Closed forest	Forest lands that have a tree-crown aerial density (crown closure percentage) of 10 percent or more, regime. Categories include deciduous, evergreen, and mixed.

Source: USGS classification system, (2007)

State of Land Use/Land Cover Classes in 2002, 2007 and 2017

In 2002, the most predominant class in the River Densu Basin was 'closed forest' which spread from the north east to the north west and was also seen dominating the eastern part of the study area and it represented 39.9% and this was followed by 'open forest' with 26.3% occupying mostly the middle portion of the study area, spreading from east to west. Bare land covered 24.7% of the river basin, spreading from the south western to the south eastern part of the area. The ‘built up’ area occupied 6.4% dominating at the south. While Farm land occupied 1.8%, water found at the south of the area occupied 1.0%, being the least (Table 8 and Figure5).

Land use/land cover units, surface areas and proportions in the River Densu Basin in the year 2007 are revealed in Table 8 and Figure 5. On the whole, ‘open forest’, the most predominant class, covered 41.8% dominating the middle to the upper section, spreading from east to west of the river basin area, making it the majority; followed by ‘closed forest’ which is seen at the middle portion and the northern part of the study area representing a decrease from 39.9% in 2002 to 28.3% in 2007. ‘Built up’ increased significantly in the area from 6.4% in 2002 to 27.7% in 2007 with total land cover dominating the southern part.

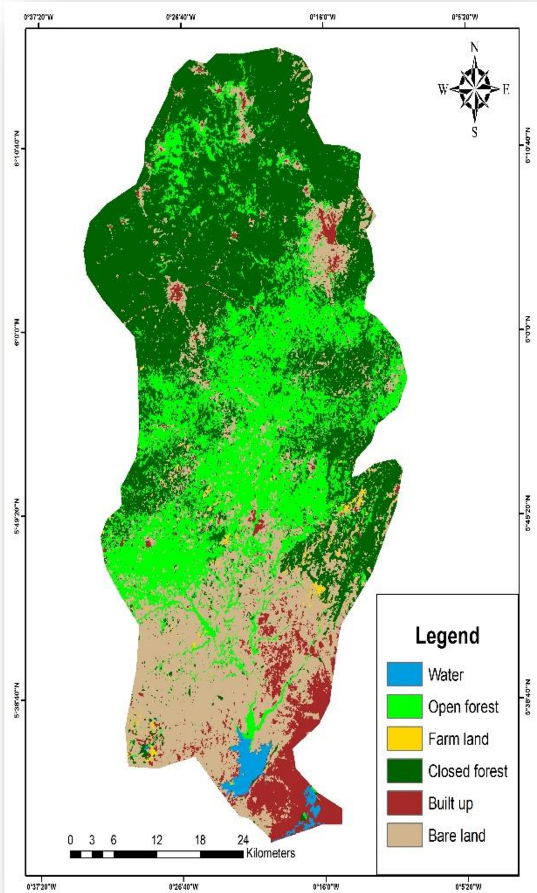
However, water increased from 1.0% in 2002 to 1.2% in 2007. ‘Bare land’ reduced strikingly from 24.7% in 2002 to 0.8% in 2007. This was found mainly at the north - north east portion of the river basin. Hence, ‘Farm land’ which is the minimum, fell from 1.8% in 2002 to 0.2% in 2007 and this is found at the west south – west of the river basin.

Land use/land cover units, surface areas and proportions in the River Densu Basin in the year 2017 are presented in Table 8 and Figure 5. On the hand, ‘built up’ increased significantly from 27.7% in 2007 to 37.7% in 2017, hence dominating the southern sector of the river basin; spreading at a faster rate precisely upwards. The ‘open forest’ fell from 41.8% in 2007 to 36.2% in 2017 hence, dominating the northern sector of the study area. Likewise, the closed forest reduced in the area from 28.3% in 2007 to 21.1% in 2017 of the total land cover. This is found at the middle portion of the river basin. On the other hand, farm land increased from 0.2% in 2007 to 2.8% in 2017. It is found more at the southern region amidst the 'built up' area of the river basin. Bare land occupied 1.4% and it is found mainly at the north east of the basin. However, water reduced noticeably from 1.2% in 2007 to 0.8% in 2017.

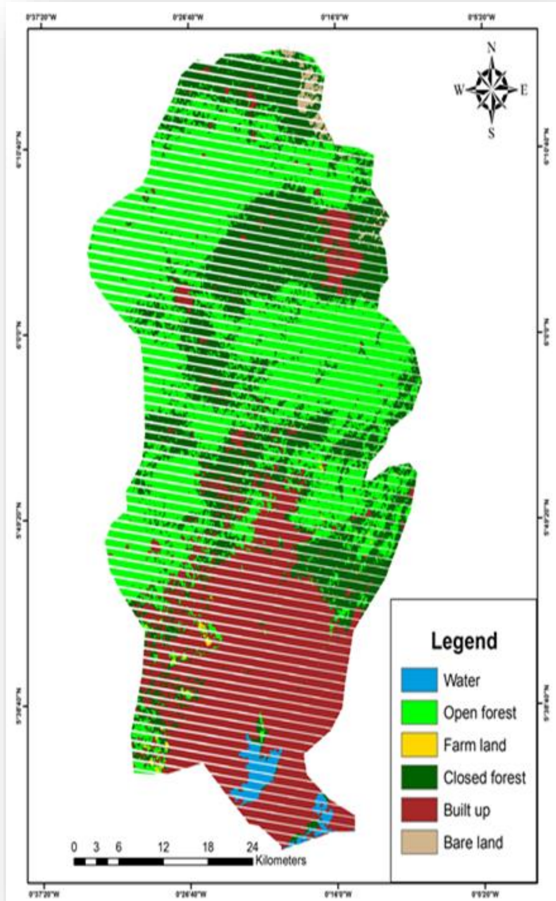
Table 8: Surface Area and percentage of Land use/cover units in 2002, 2007 and 2017

Land use/cover	Surface Area in (sq. km)			Percentage (%)		
	2002	2007	2017	2002	2007	2017
Farm lands	44.2	5.1	71.9	1.8	0.2	2.8
Water	24.6	29.6	19.9	1.0	1.2	0.8
Bare land	624.2	19.1	34.0	24.7	0.8	1.4
Built up	169.0	700.9	953.6	6.4	27.7	37.7
Closed forest	1,007.4	715.8	534.0	39.8	28.3	21.1
Open forest	664.8	1,056.7	913.8	26.3	41.8	36.2
TOTAL	**2,527.2**	**2,527.2**	**2,527.2**	**100**	**100**	**100**

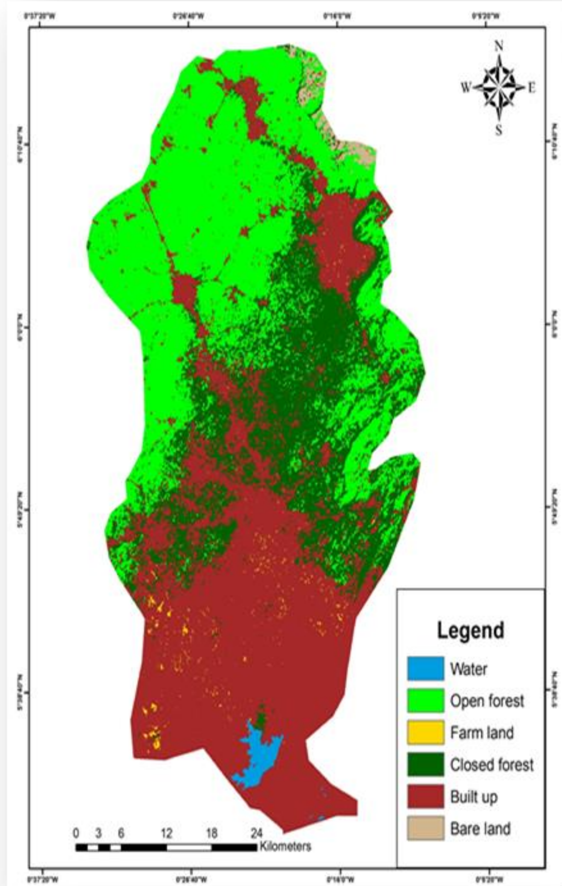
Source: Landsat 2002, 2007 and 2017 satellite images



Land use/cover classification for 2002



Land use/cover classification for 2007



Land use/cover classification for 2017

Figure 5: Land use/cover classification for 2002, 2007 and 2017

Total Changes in Land Use/Cover Classes and Drift between 2002 and 2007

The statistics, as shown in Figure 6, designates that a percentage increase of about 332.7 % sq. km in the land area was enclosed by 'Built up'. 'Open forest' increased at 59.0%. Water increased by 20.4% while farm land reduced considerably by 88.5 % just as bare land lessened by 97.0%. 'Closed forest' reduced by 29.0%.

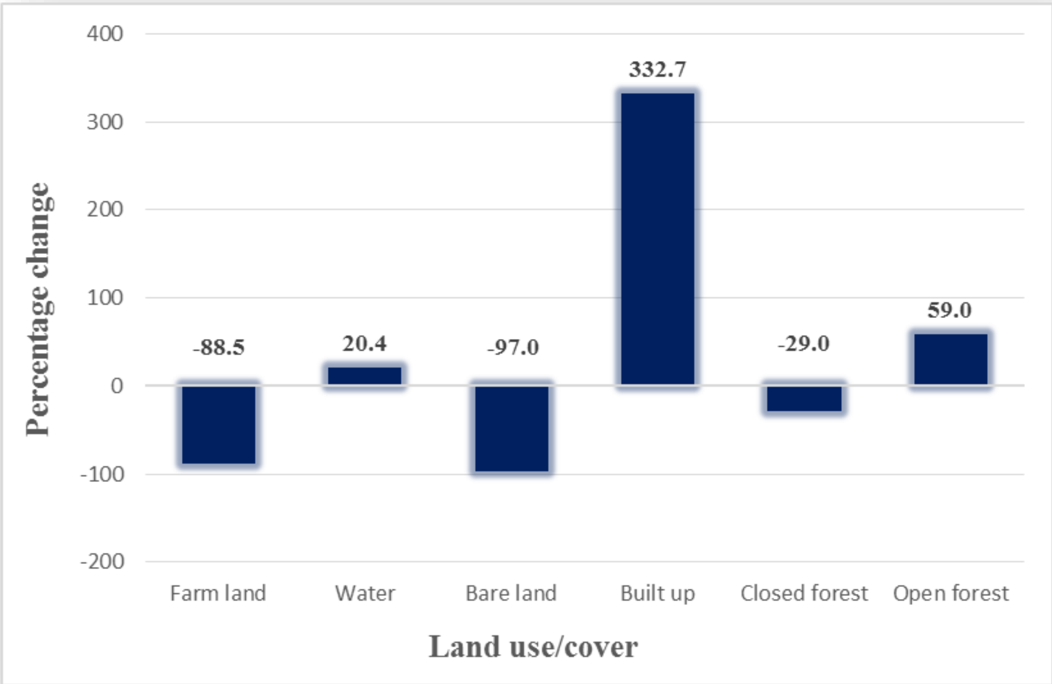


Figure 6: Percentage Change and Drift from 2002 to 2007

Source: Landsat ETM+ 2002 and ETM+2007 satellite images

Land Transformation from 2002 – 2007

As shown in Table 9 and Figure 7, 156.98sq. km of built up areas remained unchanged, 3.50 sq. km of the land cover transitioned from 'Built up' in 2002 to water in 2007, while 1.06 sq. km of built up was also transformed to farm land in the same period. Within the 5 years, 4.62 sq.km of 'built up' area also transitioned into 'open forest. In that same time, 4.89 sq. km of 'built up' areas transitioned into 'closed forest'. Besides, 382.11 sq. km of 'closed forest' stayed unchanged; 560.42 sq. km of 'closed forest' was converted into 'open forest' and 30.36 sq. km was converted to 'built-up' areas.

An assessed 386.13 sq. km of 'open forest' remained secure, whereas 191.86 sq. km of the same land cover transitioned into 'closed forest' and approximately 88.46 sq. km was converted to built-up areas. However, 0.33 sq. km of 'open forest' was converted into farm land. Hence, 412.89 sq. km was transitioned from bare lands into built-up areas while an estimated 5.17 sq. km remained unchanged. 0.53 sq. km of water was converted into 'built up' in 2007 (as shown in Table 9).

Table 9: Land Transformation 2002 - 2007

2002 / 2007	**Farm land**	**Water**	**Bare land**	**Built up**	**Closed forest**	**Open forest**
Farm land	**0.31**	0.00	0.12	11.43	14.54	17.87
Water	0.00	**25.64**	0.00	0.53	0.56	0.26
Bare land	2.69	0.004	**5.17**	412.89	121.93	87.64
Built up	1.06	3.50	0.14	**156.98**	4.89	4.62
Closed forest	0.70	0.23	13.33	30.36	**382.11**	560.42
Open forest	0.33	0.17	0.31	88.46	191.86	**386.13**

(Figures **bolded** in Table 9 above indicates various land use/cover which remained unchanged)

Source: Landsat ETM+ 2002 and ETM+2007 satellite images

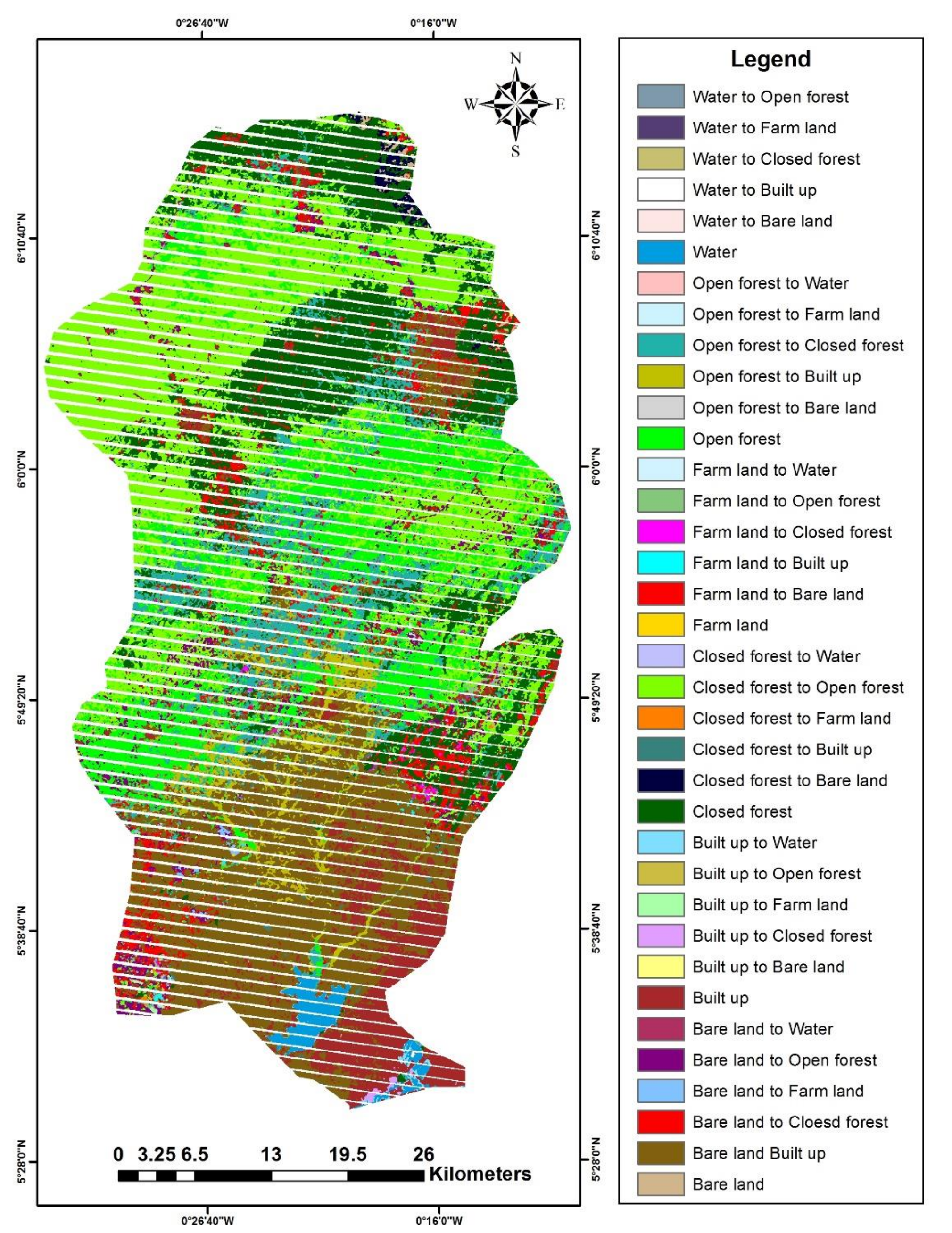


Figure 7: Result of the Post Classification for 2002 and 2007

Source: Landsat ETM+ 2002 and ETM+2007 satellite images

Total Depletion of Land Use/Cover between 2002 and 2007

As shown in Figure 8, an estimated number of 625.15 sq. km of bare lands, representing 40% were depleted in the river basin into other land use/cover areas. Also, 605.04 sq. km of the closed forest were depleted thus, representing 38% of the total number of land use/cover that were depleted. This tells the extent to which deforestation is prevalent. The open forest was depleted by 281.13 sq. km, representing 18%; an estimated 43.96 sq. km, representing 3% of Farm lands were lost. However, 1% making 14.21 sq. km of built ups were demolished in the River Densu basin.

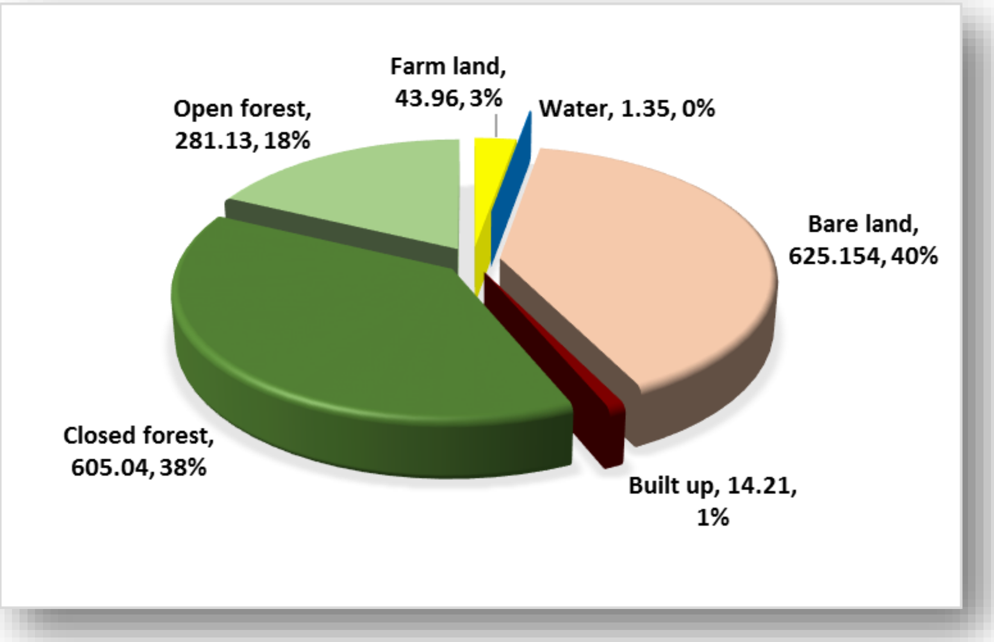


Figure 8: Depletion of Land use/cover between 2002 and 2007

Source: Landsat ETM+ 2002 and ETM+2007 satellite images

Total Changes in Land Use/Cover Classes and Drift between 2007 and 2017

The statistics, as revealed in Figure 9, specifies a percentage increase of 1,311.0% sq. km in the land area covered by farm land. Bare land increased by 78.5%. Water fell considerably by 32.9% while built up areas increased by 36.1%. However, open forest reduced slightly by 13.5% and closed forest lessened noticeably by 25.4%.

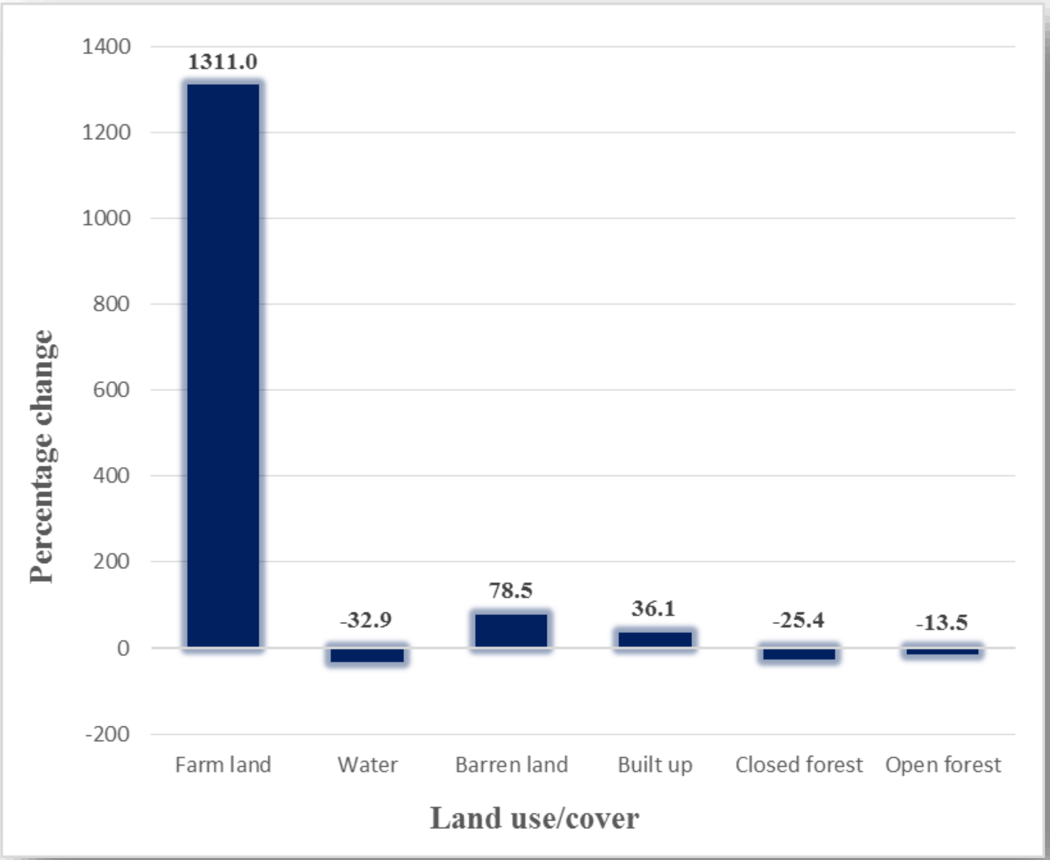


Figure 9: Percentage change and drift from 2007 to 2017

Source: Landsat ETM+ 2007 and OLI/TIR 2017 satellite images

Land Transformation from 2007 – 2017

As shown in Table 10 and Figure 10, 612.01sq. km of built up areas remained unchanged, 0.20 sq. km of the land cover transitioned from built up areas in 2007 to water in 2017, while 43.62 sq. km of built up area was also transformed into Farm land in the same period. In the region of 16.42 sq. km of built up area was also transitioned into open forest. In that same time, 28.14 sq. km of built up transitioned into closed forest. Besides, 208.55 sq. km of closed forest stayed unchanged; 292.66 sq. km of this land cover was converted into open forest and 184.82 sq. km was converted to Built-up areas.

An amount of 572.32 sq. km of open forest remained protected, whereas 306.45 sq. km of the same land cover transitioned into closed forest; and 154.42 sq. km was converted to built-up areas. However, 11.11 sq. km of open forest was changed into farm land. Hence, 2.29 sq. km of the river basin was changed from bare lands into built-up areas while an estimated 8.77 sq. km remained unchanged; 9.16 sq. km of Water was converted into built up and 0.42 sq. km of Farm land remained unchanged in 2017.

Table 10: Land Transformation 2007 - 2017

2007 / 2017	Farm land	Water	Bare land	Built up	Closed forest	Open forest
Farm land	**0.42**	0.00	0.002	4.51	0.11	0.04
Water	0.00	**20.46**	0.00	9.16	0.00	0.00
Bare land	0.03	0.00	**8.77**	2.29	1.54	6.43
Built up	43.62	0.20	0.53	**612.01**	28.14	16.42
Closed forest	17.30	0.33	12.13	184.82	**208.55**	292.66
Open forest	11.11	0.14	12.26	154.42	306.45	**572.32**

(Figures **bolded** in Table12 above indicates various land use/cover which remain unchanged)

Source: Landsat ETM+ 2007 and OLI/TIR 2017 satellite images

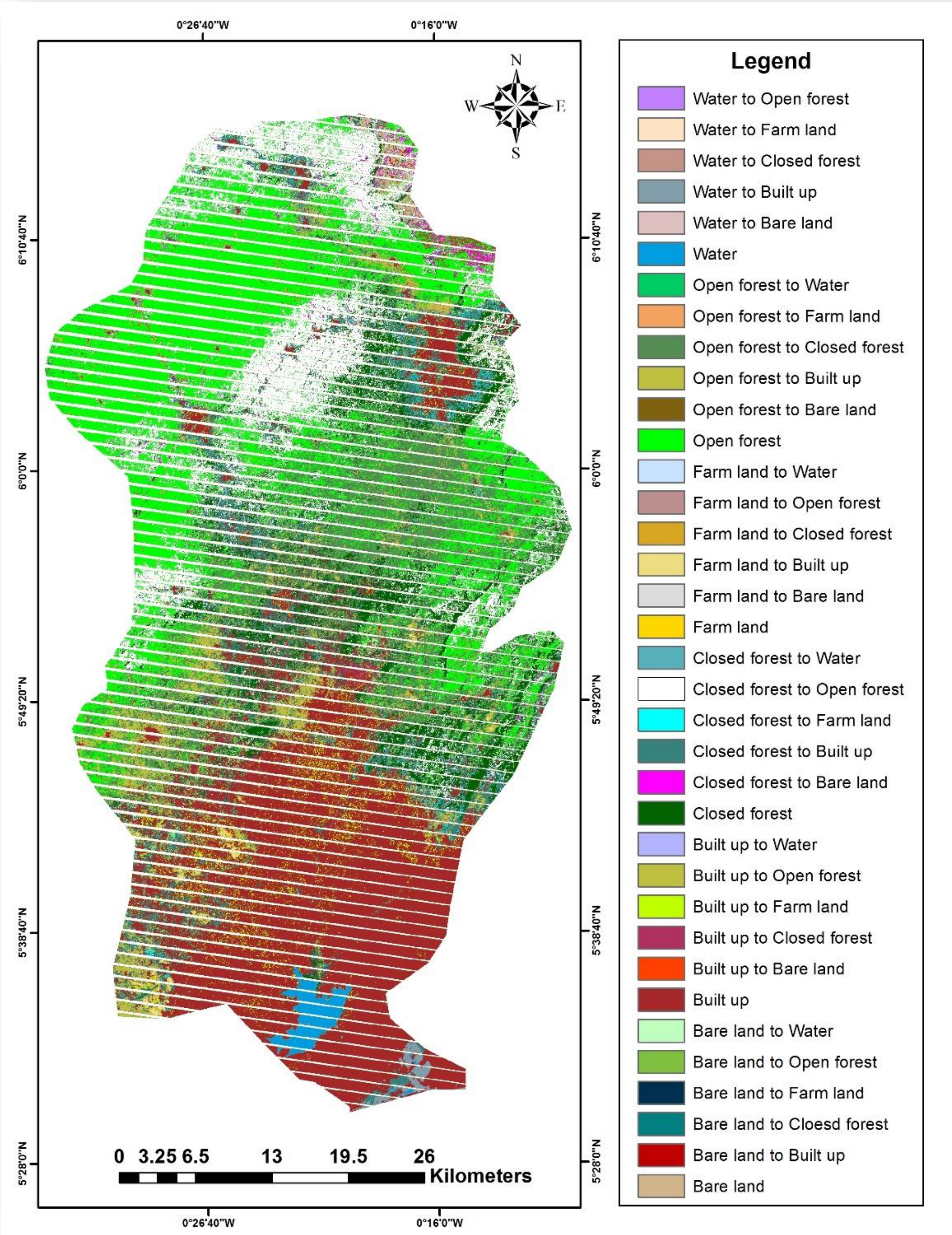


Figure 10: Result of the Post Classification for 2007 and 2017

Source: Landsat ETM+ 2007 and OLI/TIR 2017 satellite images

Total Depletion of Land Use/Cover between 2007 and 2017

As shown in Figure 11, 762.86 sq. km of the closed forest, representing 41% was depleted in the River Basin. Also, 617.03 sq. km of bare land were depleted, thus, representing 33% of the total number of land use/cover that were depleted. The Open forest was depleted by 443.27 sq. km, representing 24%; an estimated 41.01 sq. km, representing 2% of Farm lands were lost. However, less than 0.0% of Water and Built ups were encroached on in the River Densu Basin, thus making 5.59 and 2.94 sq. km correspondingly.

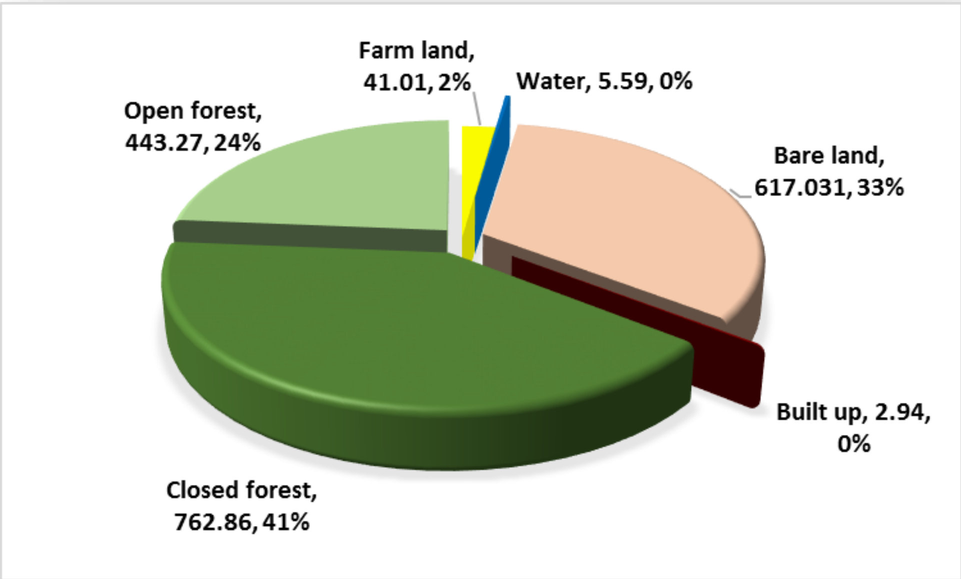


Figure 11: Depletion of Land use/cover between 2007 and 2017

Source: Landsat ETM+ 2007 and OLI/TIR 2017 satellite images

Total Changes in Land Use/Cover Classes and Drift between 2002 and 2017

The statistics, as presented in Figure 12, shows a tremendous percentage increase of about 488.8% of sq. km in the land area covered by built ups. Water fell considerably by 19.1% while farm land increased very significantly by 62.6%; open forest increased noticeably by 37.5%. However, closed forest reduced by 47.0% and Bare land diminished very marginally by 94.6%.

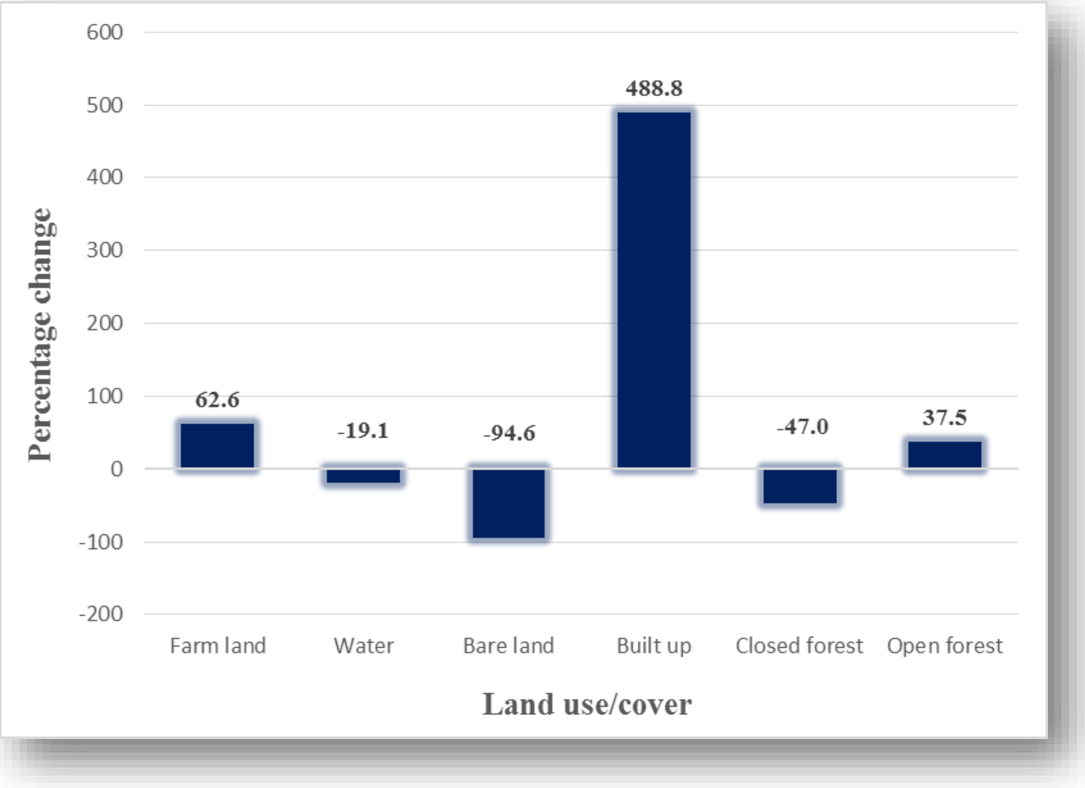


Figure 12: Percentage Change and Drift from 2002 to 2017

Source: Landsat ETM+ 2002 and OLI/TIR 2017 satellite images

Land Transformation from 2002 – 2017

As displayed in Table 11 and Figure 13; 159.75 sq. km of built up area remained unchanged, 0.11 sq. km (3.50 sq. km in 2007) of the land cover transitioned from built ups in 2002 to water in 2017, while 2.06 sq. km (1.06 sq. km in 2007) of built ups were also transformed to farm land in the same period. In the region of 0.31 sq. km (4.62 sq. km in 2007) of built ups also +-transitioned into open forest. In the same period of time, 0.36 sq. km (4.89 sq. km in 2007) of built up transitioned into closed forest. Furthermore, as 241.05 sq. km of closed forest remained unchanged, 634.31 sq. km (560.42 sq. km in 2007) of this land cover transitioned into open forest and 97.91 sq. km (30.36 sq. km in 2007) was converted to Built-up areas.

An estimated 224.67 sq. km of open forest remained stable, whereas 224.80 sq. km (191.86 sq. km in 2007) of the land cover transitioned into closed forest and 180.56 sq. km (88.46 sq. km in 2007) was transformed into built-up areas. However, 13.68 sq. km (0.33 sq. km in 2007) of open forest was converted into farm land. Hence, 486.68 sq. km (412.89 sq. km in 2007) of land was transited from bare lands into built up areas while an estimated 6.95 sq. km remained unchanged. 5.53 sq. km (0.53 sq. km in 2007) of Water was transformed into built up area in 2017.

Table 11: Land Transformation 2002 - 2017

2002 / 2017	**Farm land**	**Water**	**Bare land**	**Built up**	**Closed forest**	**Open forest**
Farm land	**2.41**	0.00	0.19	22.85	7.87	10.10
Water	0.00	**19.65**	0.00	5.53	0.06	0.00
Bare land	45.75	0.001	**6.95**	486.68	40.02	44.58
Built up	2.09	0.11	0.07	**159.75**	0.36	0.31
Closed forest	7.93	0.10	22.61	97.91	**241.05**	634.31
Open forest	13.68	0.04	4.19	180.56	244.80	**224.67**

(Figures **bolded** in Table11 above indicates various land use/cover which remain unchanged)

Source: Landsat ETM+ 2002 and OLI/TIR 2017 satellite images

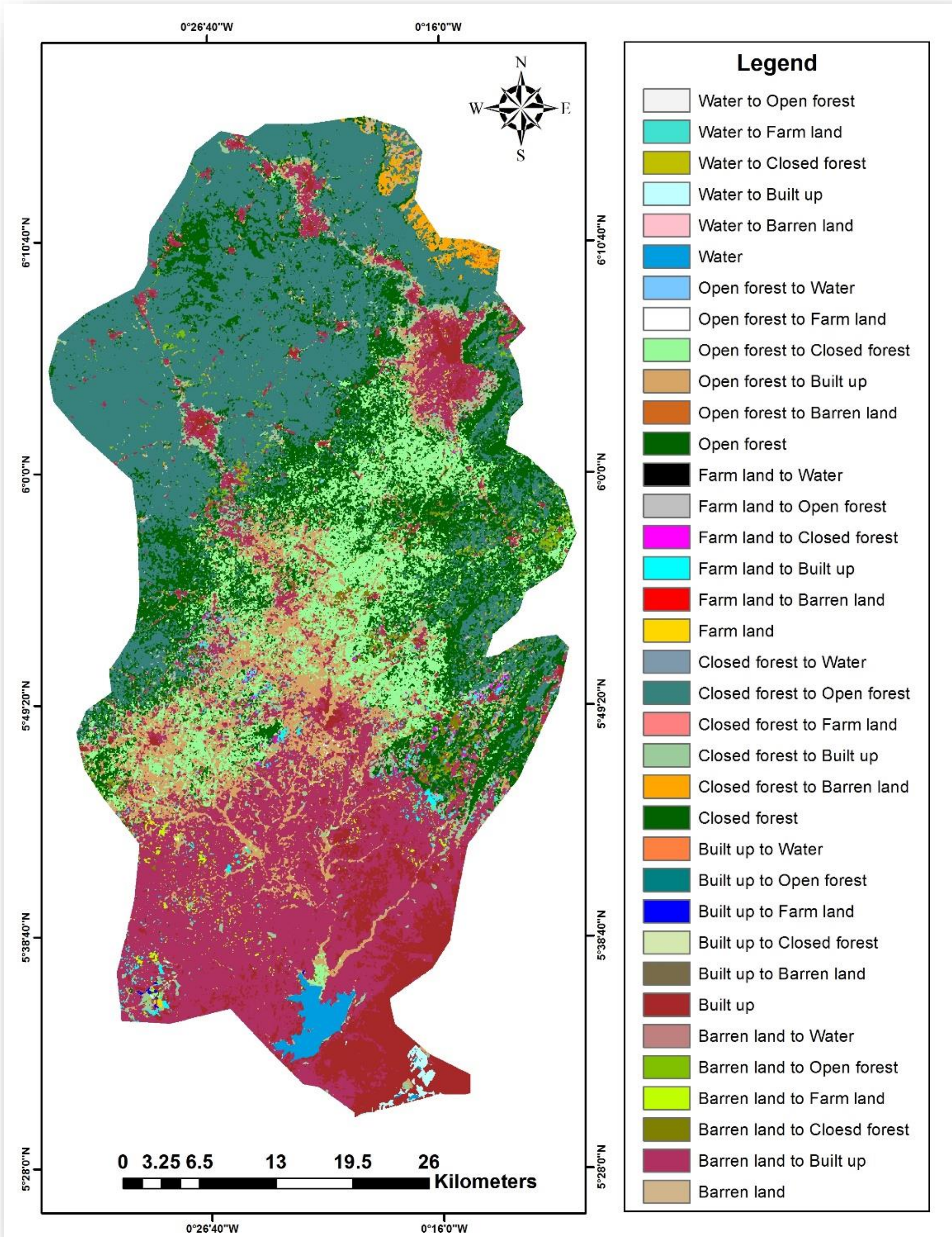


Figure 13: Result of the Post Classification for 2002 and 2017

Source: Landsat ETM+ 2002 and OLI/TIR 2017 satellite images

Total Depletion of Land Use/Cover between 2002 and 2017

As shown in Figure14, an estimated number of 507.24 sq. km of the ‘closed forest’, representing 46% was depleted in the River Basin into other land use/cover areas within this fourteen (14) year period. Also, the ‘open forest’ was depleted by 484.38 sq. km, representing 44%. 10.29 sq. km of bare land was depleted, thus, representing 9% of the total number of land use/cover that was depleted. However, 9.61 sq. km, representing 1% of water was lost. ‘Built up’ areas of the river basin were exhausted at 88.91 sq. km, thus representing 8% of the total number of land use/cover that was depleted. On the other hand, less than 0.0% making 4.65 sq. km of farm lands was trespassed.

Therefore, one thing to consider critically over this period (2002 – 2017) is that, the forest zones (closed and open forest) of the River Densu basin was encroached at an estimated total number of 991.62 sq. km; thus representing 90% of the total number of land use/cover depleted.

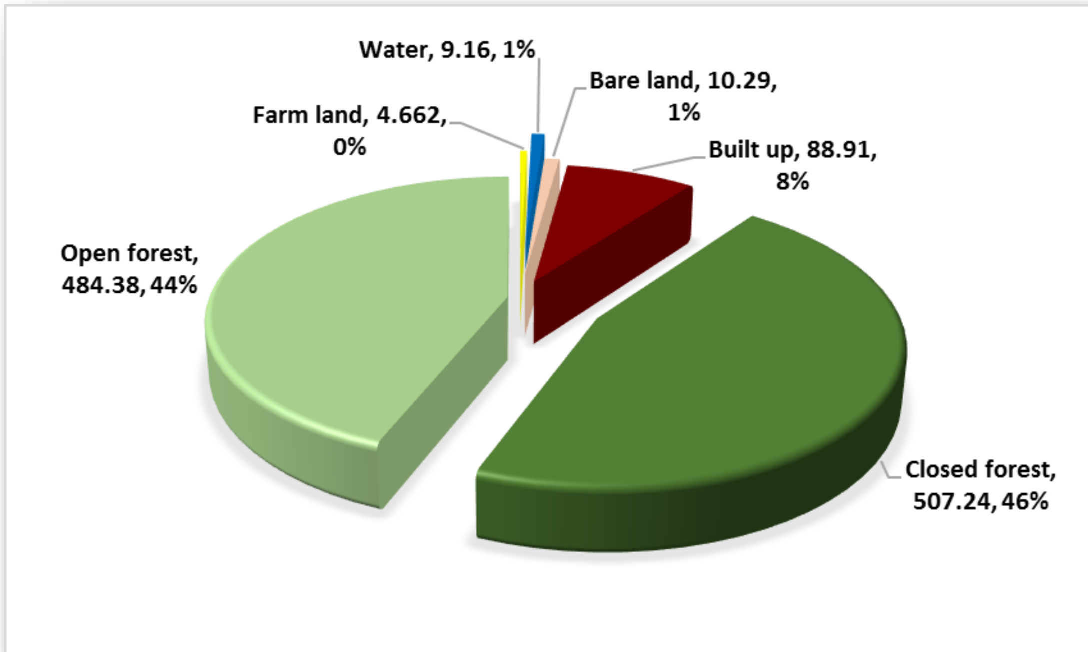


Figure 14: Depletion of Land use/cover between 2002 and 2017

Source: Landsat ETM+ 2002 and OLI/TIR 2017 satellite images

Discussions on Land Use/Cover variations

Land Use/Land Cover (LULC) mapping is generated mainly to reproduce the earth surface by delimiting diverse features as they occur in the natural environment. LULC is a phenomenon that greatly affects natural landscape most specifically in rapidly developing and urbanized areas of most unindustrialized countries (Lambin et al., 2001). Observing these variations of 'feature' and 'phenomenon' on earth is progressively dependent on LULC maps generated from multi temporal remotely sensed data.

Land use Land Cover Variations for 2002-2007

One of the observations made in the land use/cover variations in the River Densu basin from 2002 to 2007 was the decrease in the area of farm lands from 44.2 sq. km to 5.1 sq. km (Table 8). As specified in Table 9, 11.54 sq. km of farm lands were converted to 'built-ups', while 0.31 sq. km remained unchanged.

This was as a result of the fast increase of 'built-ups' from 169.0 sq. km to 700.9 sq. km (Table 8) due to the growth of urbanization in relation to population increase from 1,054,915 in 2002 to 1,200,457 in 2007 which indicates a percentage increment of 13.8. As a matter of fact, many farm lands were given out due to high demand of land for the construction of infrastructure such as roads, houses, public and private state properties, utility facilities and so on.

Another observation made in the land use/cover variations in the River Densu basin from 2002 to 2007 was the reduction of the 'closed forest' from 1,007.4 sq. km in 2002 to 715.8 sq. km in 2007 (as shown in Table 8). In fact, the total estimation from 2002–2007 (1,875.14 sq. km) of the transformation of some portion of the closed forest in the River Densu Basin, tells the extent of deforestation in the area. Consequently, most of it was converted into 'open forest' of about 560.42 sq. km as shown in Table 9, making it an area with shrubs and patches of bare soil, sparsely located trees, isolated thicket and an extensive grass cover.

This is as a result of the increase in demand for food consumption and artifacts made of trees due to high population growth. As a result, the forests were encroached since it is one of the sources of wood for building construction and firewood and the avenue for crop cultivation. For instance, in the rural areas, firewood is the most important source of energy. According to Aheto et al., (2014) firewood from forests are commercialized as its demand has increased particularly in areas which are devoid of trees and in some urban settings and thus, the place of study is no exception. All these make up the most important consequences and shortfalls worthy of consideration in this particular era. Subsequently, the decrease in forest cover can lead to other environmental problems such as increase in land degradation, soil erosion and abating of the biodiversity.

Another observation made in the land use/cover variations in the River Densu basin from 2002 to 2007 is the substantial decrease in the total areas of bare land from 624.2 sq. km in the former year to 19.1 sq. km in the latter depicting a very striking decrease of 97.0 % as revealed in Figure 6. Hence, paving the way for 'built-ups' thereby 412.89 sq. km of bare lands were transformed into build-ups (as shown in Table 9). Lucidly, it seems that, the fast increase of 'built-ups' as an outcome of urbanization is either affecting the land masses of the various land use/covers in a direct way as in encroachment or in an indirect way as in mounting pressures in the depletion of them, especially the 'closed forest' and 'open forest' covers.

It could be argued that, the increase of water over the period is due to high rain falls occurring between these periods. An effect of this is the increase of the water table serving as one of the inflows of water to majority of storages in the hydrological cycle and the River Densu basin is no exception. Within certain considerable seasons, the Weija reservoir is opened for the outlet of excess water due to its high rise. Hence, the increase in water cover over the period is a contributing factor to this scenario. However, the River basin may also experience some rains because of the presence of forest cover which seems to spread evenly in the River basin as depicted in Figure 5. Besides, the volume of water can fall at any time or rise if other factors are mostly considered.

Land use/ Cover Variations for 2007-2017

Changes in land use/cover classes and trend between 2007 and 2017 in the basin of River Densu have experienced a similar increase in the area cover of farm land as it occurred within the period of 2002 to 2017. Nevertheless, in this era, there has been tremendous increase of the percentage change in farm lands at 1,311. About 71.43 sq. km (Table 10, column 2) of lands from other land use/cover excluding water (0.00 sq. km from Table 9 and 10 respectively) have been converted to farming plots.

Normally, it is anticipated that as urbanization spreads, farm lands get depleted based on the definition that, urbanization is as a result of the people migrating from rural areas to settle in urban areas; thus, leaving or selling their properties especially farm lands in order to get enough money to begin life afresh in the cities. Undoubtedly, such a definition of urbanization holds but it is not always the case since the outcome of its growth will decrease the number of farm lands as witnessed in the River Densu Basin in the period between 2007 and 2017.

It could be, that certain factors such as weather events (as in rain), economic policies and other projects in relation to agriculture were very favorable (within a period of the ten years that is, 2007 to 2017) for crops (in terms of the weather) and/or farmers (in terms of economic policies and agricultural projects) to cultivate more crops by acquiring more lands; and this may be one of the reasons why bare land increased in percentage by 78.5%; indicating that some lands might have been cleared for farm extensions during that era. This then results in the encroachment of other land use/cover especially water at 32.9%, as well as the possibility of 'closed' and 'open forests' decreasing in land area of 25.4 and 13.5 percent respectively (Figure 9) in the River Densu basin.

Land Use Land Cover Variations 2002-2017

Observation made from the 2002 to 2017 land use/cover variations in the River Densu Basin maintains that, built-ups gained more land area of about 793.53 sq. km (Table 11 column 5) from the various land use/cover areas, hence spreading from the southern section towards the middle and western section and a slight increase at the north eastern section of the River Basin as depicted in Figure 5. These show how urbanization is gradually spreading into forest zones. These lands are purchased mostly by estate developing companies for building houses which in turn help to solve housing problems in these urbanized communities. Again, majority of people in the urban zones tend to acquire houses which were closer to their places of work which subsequently resulted in the issues of high rent rate and the shortage of houses.

Unfortunately, most plots of lands acquired by individuals and estate developers were cleared and left bare for longer periods (delay in the settlement of land disputes in courts could be a factor) thereby exposing the land to agents of erosion and desertification. This could therefore be one of the causes of the high upsurge of bare lands (624.2 sq. km; Table 8) in the River Densu basin in 2002 (Figure 5). The expansion of 'built-up' areas is directly associated to population growth within the period between 2002 and 2017. For instance, the population of people in the River Densu basin increased from 1,054,915 in 2002 to 1,366,483 in 2016 (Table 6). Therefore, growth in human population during this period had in turn resulted in the acquisition of extra lands for settlements through the encroachment of the forest.

It is right to state that some rural areas are gradually becoming urbanized due to the fact that some towns in the rural set ups have been linked with major truck roads and facilitated with certain infrastructural developments as in the case of the number of District Assembles in the country being increased in these periods. Hence, indigenes in such areas are embedded with some beauties of life, conveniences in livelihood and improved health delivery and facilities as the positive sides of developments which may in turn convince them from the necessity to migrate to more urbanized towns. Thus, in the long run, the population in the various rural towns or districts will increase.

The last observations made in the land use/cover variations in the River Densu Basin from 2002 to 2017, is the high increase of farm lands. It increased significantly from 44.2 sq.km in 2002 to 71.9 sq.km in 2017 (Figure 5 and Table

8) with an increase in percentage change of 62.6 (Figure 12). An estimation of 69.45 sq. km (Table 11, column 2) of the various land use/ cover with the exception of water was transformed into farm lands. This can be linked to the demands to engage in increased crop cultivation to cater for the growth in the population of this area. It is therefore not very surprising to witness how 'built-ups' and farm lands have increased in these periods.

Discerning from the period running through 2002, 2007 to 2017; an era of five years (2002 – 2007) and ten years (2007 – 2017), it is obvious that, amidst the various land use/cover classes, 'built-up' is the only land use which had a substantial increase in land area from 169.0 sq. km in 2002 to 700.9 sq. km in 2007; and from 700.9 to 953.6 sq. km in 2007 and 2017 in that order (Table 8). Rationally, it seems that, the rapid increase of 'built ups' as an outcome of urbanization due to population increase is either affecting the land masses of the various land use/covers in a direct way as in encroachment or in an indirect way as in mounting pressures its depletion, especially the 'closed' and 'open forest' covers.

CHAPTER FIVE

PHYSIO-CHEMICAL ANALYSIS OF RAW WATER

Introduction

This chapter presents the results and discussions that were deduced from data on water quality parameters. The chapter captures the trend analysis of yearly average recordings on water quality parameters and existing relationships between urbanization and quality of water.

Results of Trend Analysis of Water Quality Parameters

Phosphate

From the Figure 15, the highest average phosphate content in the Weija reservoir was recorded in the year 2015 which was 10.9mg/L whilst 2013 recorded the lowest average phosphate content of 0.1mg/L. The other remaining years recorded very minimal average recordings which were slightly above the average recordings of 2013

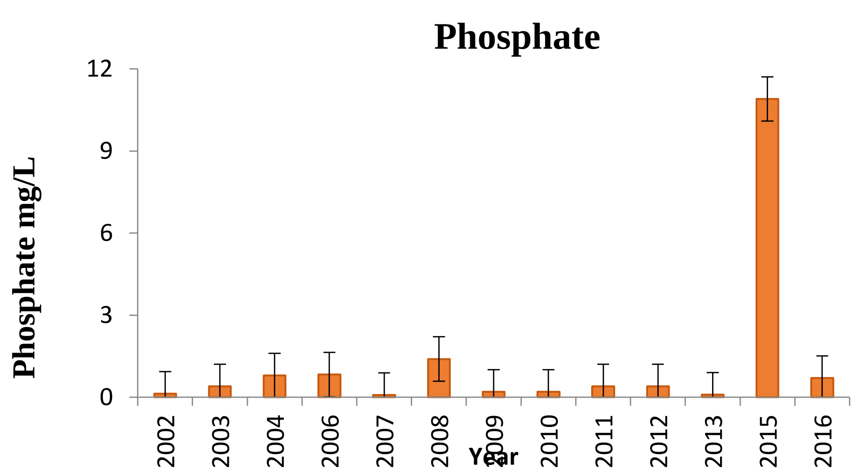


Figure15: Level of phosphate in raw water (no guideline value)

Source: Data on water quality parameters from WHW

Nitrate

Findings revealed that, in 2003 and 2015, Nitrate recorded high levels of 3.9mg/L and 4.9mg/L respectively while in 2006, 2011, 2012 and 2013, the nitrate level was very negligible. It could also be observed that nitrate levels started decreasing in 2008 through to 2013 after which it increased in the years 2015 and 2016.

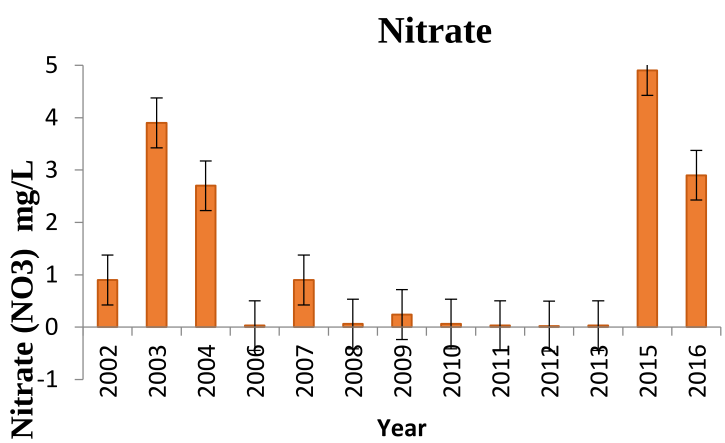


Figure16: Level of nitrate in raw water (WHO max. -50mg/L)

Source: Data on water quality parameters from WHW

Ammonia

The record shows that, in 2012, the level of ammonia in the water sample was 0.6 mg/l which represented the highest average recording year while in 2015 and 2016 ammonia was either null or very insignificant. It could also be observed that ammonia increased in 2003 and 2004 while its content in the water started decreasing from 2008 through to 2011. Although the highest average content was recorded in 2012, ammonia content in the water decreased tremendously in the years 2013, 2015 and 2016.

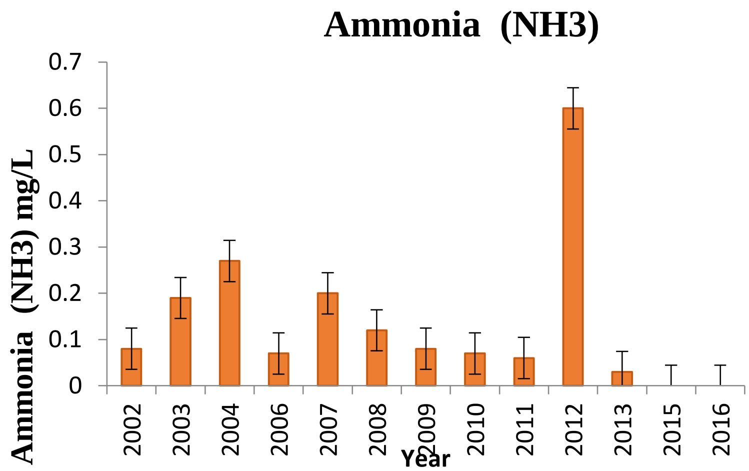


Figure 17: Level of Ammonia in raw water (WHO max. - 1.5mg/L)

Source: Data on water quality parameters from WHW

Turbidity

Figure 18 indicates average levels of turbidity in raw water samples from 2002-2016. The figure shows that 2003 and 2004 recorded the highest levels of turbidity with recordings being 25NTU and 21.9 NTU respectively while 2013 recorded 7.4 NTU which happened to be the lowest recording.

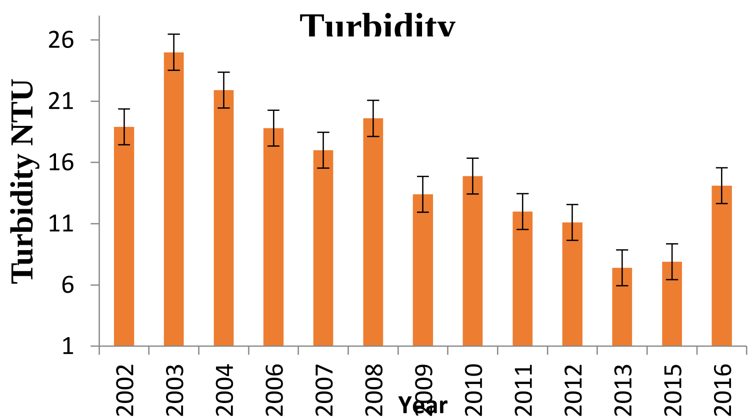


Figure 18: Level of turbidity in raw water (WHO max. - 5 NTU)

Source: Data on water quality parameters from WHW

Colour

Figure 19 below indicates the colour of raw water samples recorded from 2002 to 2016. It was realized that average levels of water colour were very high as compared to what the World Health Organization has established (15 TCU). The figure shows that the highest average recording was made in 2003 which was 157 TCU while in 2015 it was observed that the colour level had reduced to 68 TCU. It can also be observed from the figure 19 that after 2009, the level of colour of water kept on improving.

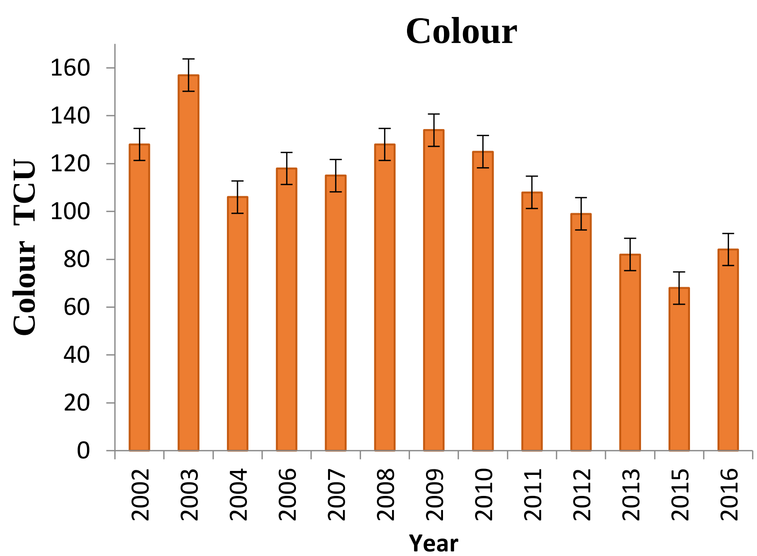


Figure 19: Level of colour (apparent) in raw water (WHO max.-15 TCU)

Source: Data on water quality parameters from WHW

pH

Figure 20 indicates the levels of pH of raw water samples from 2002 - 2016. In 2002, 2004 and 2015, the level of pH was high at 7.9 while in 2006, 2007, 2008 and 2011; pH recorded a lower value of 7.5.

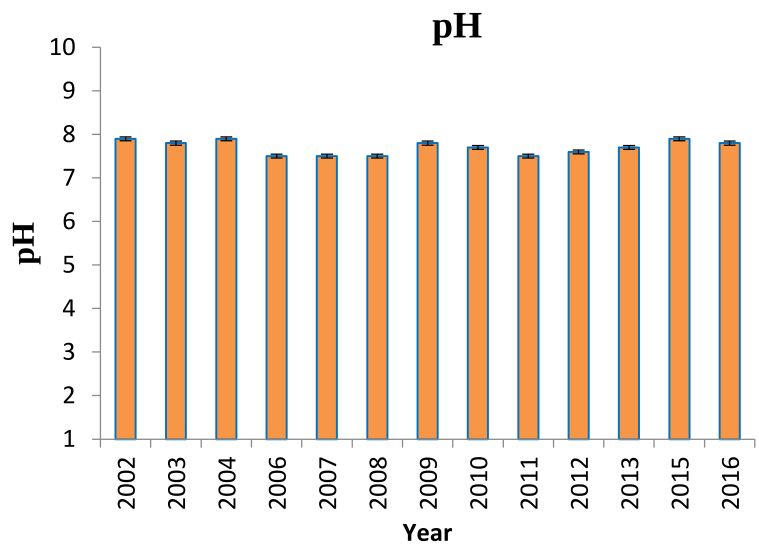


Figure 20: Level of pH in raw water (WHO min. 6.5- max. 8.5)

Source: Data on water quality parameters from WHW

Temperature

It was observed that the results of analysis for temperature fell between the ranges of 25.6 - 28.7 degree Celsius and it is represented graphically below;

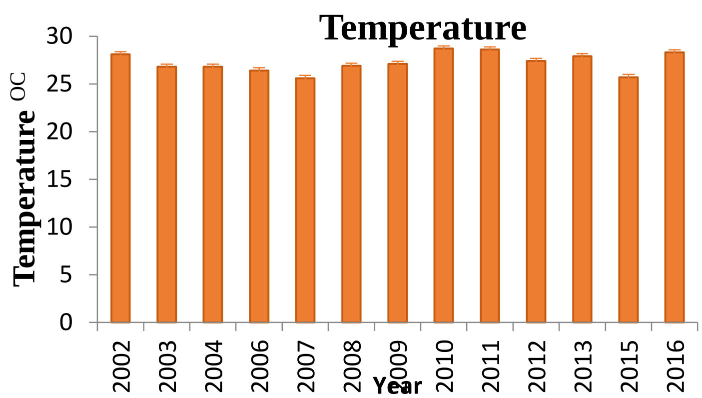


Figure 21: Level of temperature in raw water (no guideline value)

Source: Data on water quality parameters from WHW

Sulphate

Figure 22 indicates a presentation of average levels of sulphate present in raw water samples from 2002 - 2016. The lowest average recordings were made in 2002 and 2007 whilst the highest was made in 2003. The figure clearly shows that sulphate recorded very low levels of less than 50mg/L throughout the 14 years.

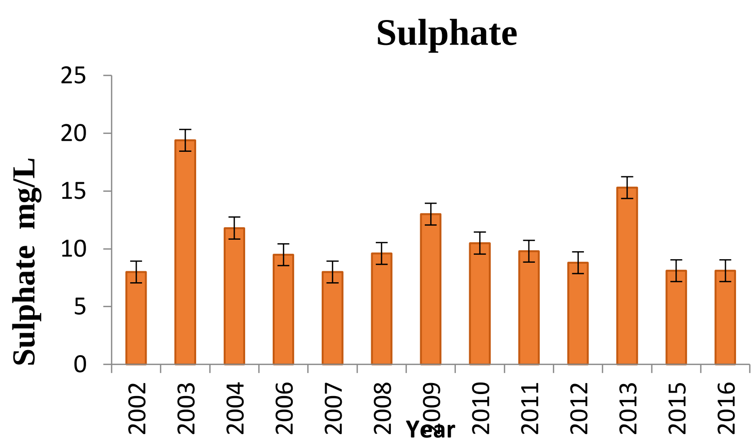


Figure 22: Level of sulphate in raw water (WHO max – 500mg/L, GSBGV max – 250mg/L)

Source: Data on water quality parameters from WHW

Iron

Figure 23 indicates the Iron levels in raw water samples analyzed from 2002 to 2016. It was revealed that, in 2012, the highest average level of Iron (1.7mg/L) in water from the Weija reservoir was recorded. The record also shows that, the second highest recording was made in 2015 which was 0.3 mg/L while in the remaining years, iron levels were very low.

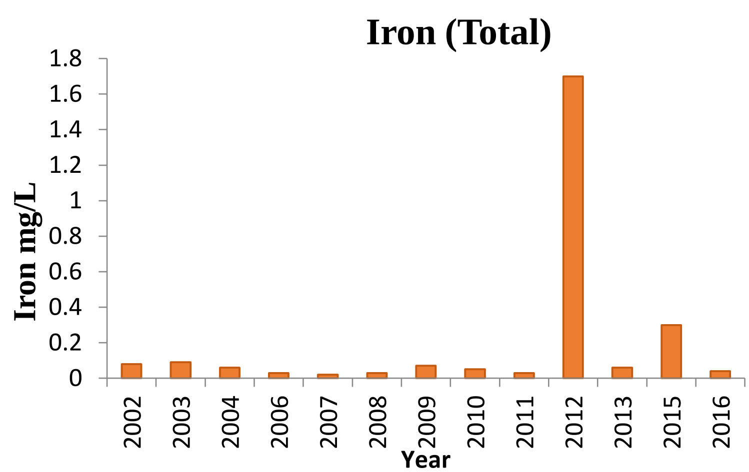


Figure 23: Level of iron (total) in raw water (WHO max. – 0.3mg/L)

Source: Data on water quality parameters from WHW

Fluoride

It was observed from Figure 24 that recordings for fluoride fell within the WHO guideline values. In 2015, 2003, 2004 and 2007, Fluoride levels in water samples which were analyzed were higher than other years. The Figure also shows that, in some years, such as 2002, 2012 and 2016, the levels of Fluoride in the water samples were negligible.

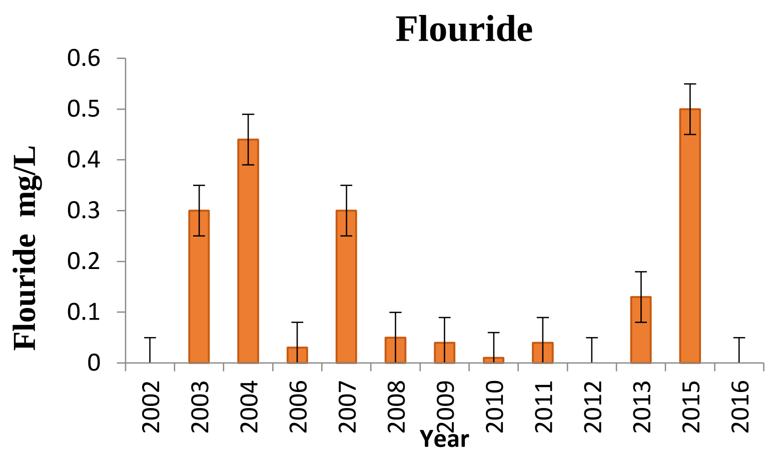


Figure 24: Level of Fluoride in raw water (WHO max. – 1.5 mg/L)

Source: Data on water quality parameters from WHW

Total Solids

It can be seen from Figure 25 that the average recordings of total solids were all bellow the 1000mg/L max value established by WHO. It can also be observed that the lowest average Total Solids content was recorded in the year 2002 which was 120mg/L while the highest content was recorded in 2016 which was 220mg/L.

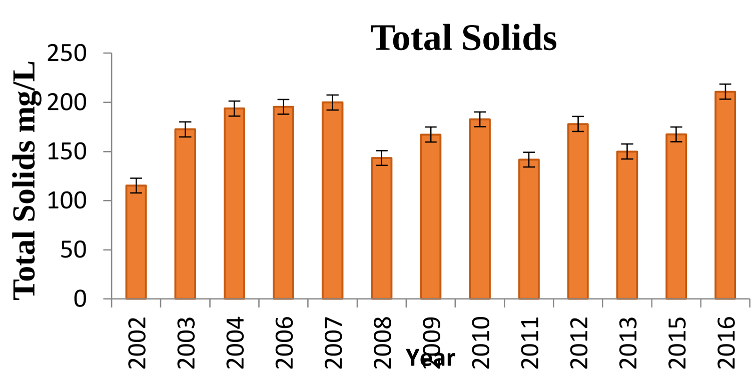


Figure 25: Level of Total solids in raw water (WHO max. – 1000mg/L)

Source: Data on water quality parameters from WHW

Suspended Solids

Deductions from Figure 26 inform that among the 14 years, 2011 recorded the least level of suspended solids whilst 2016 recorded the highest concentration. It is also revealed that after 2004, suspended solids level started decreasing through to 2012 after which its constituent started increasing from 2013 through to 2016.

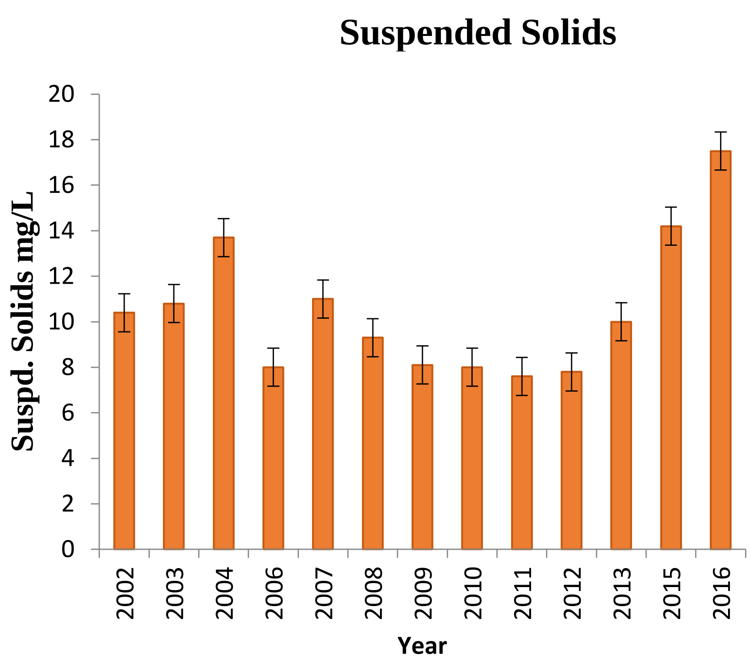


Figure 26: Level of suspended solids in raw water (no guideline value).

Source: Data on water quality parameters from WHW

Total Dissolved Solids

The Figure 27 gives an account of the level of TDS in water samples which was recorded from 2002 to 2016. The figure depicts that, 2002 and 2008 recorded low levels of total dissolved solids, being 109.8mg/L and 133.1 mg/L respectively while 2004 and 2016 recorded higher levels of 196.8mg/L and 193.5mg/L respectively.

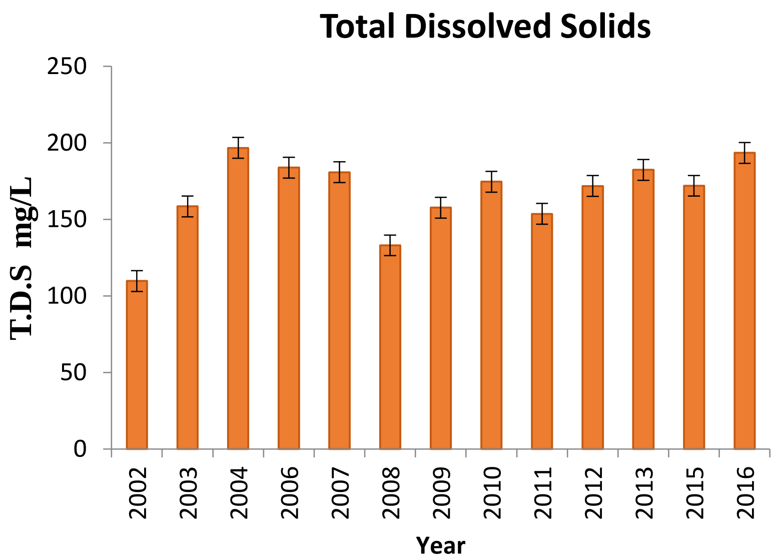


Figure 27: Level of T.D.S in raw water (WHO. Min. 500 mg/L- max. 1000 mg/L)

Source: Data on water quality parameters from WHW

Total Hardness

Figure 28 illustrates the average levels of hardness of water that were recorded from the Weija Reservoir for a period of 14 years. The figure shows that the level of hardness attained its highest average recording in 2016 which was 120 mg/L while the remaining years had recordings between 60mg/L and 97.7mg/L. It could be observed from the figure that the level of hardness in the water started decreasing after 2002 through to 2007, after which it started increasing in 2008 through to 2016.

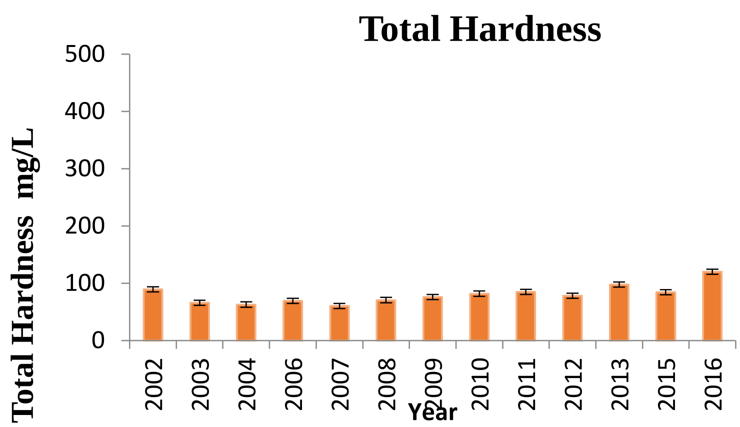


Figure 28: Level of Total Hardness in raw water (WHO max. – 500mg/L)

Source: Data on water quality parameters from WHW

Calcium

It was observed from figure 29 below that the results from the recordings for calcium fell within WHO guideline value except 2007, which recorded 158.4mg/L. It was also revealed that the calcium content in the water started decreasing in 2003 through to 2007, after which it tremendously dropped in 2008 but subsequently started increasing afterwards.

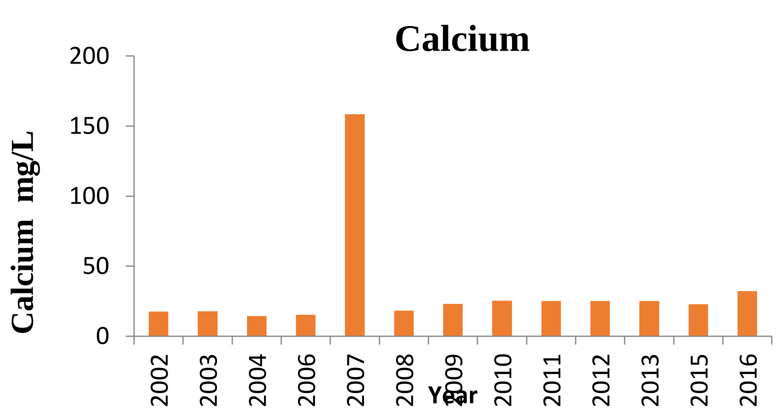


Figure 29: Level of calcium in raw water (WHO max.- 50mg/L)

Source: Data on water quality parameters from WHW

Magnesium

It was observed that among the 14 years, 2016 recorded the highest magnesium content which was 11.9mg/L while 2010 recorded the lowest magnesium content at 4.4mg/L. It was further observed that recordings decreased drastically after 2003 through to 2011, after which it started increasing through to 2016.

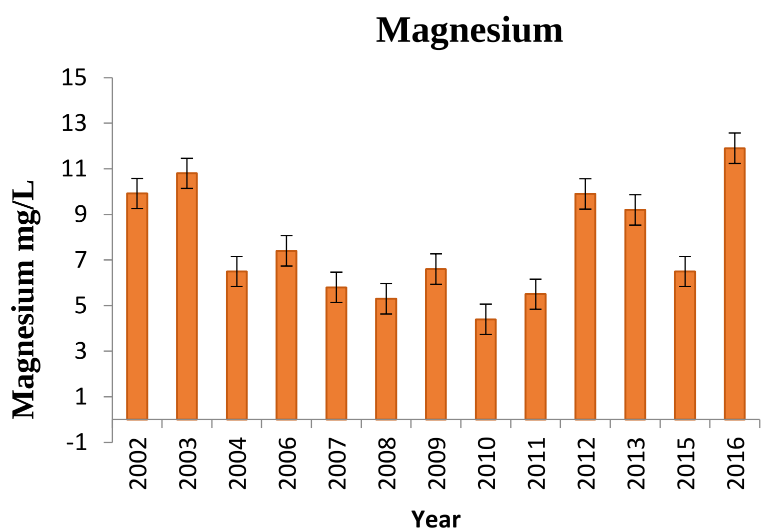


Figure 30: Level of Magnesium in raw water (WHO max. 30mg/L)

Source: Data on water quality parameters from WHW

Discussions on Trend Analysis of Water Quality Parameters

Physico-chemical Parameters

Phosphate

Excessive quantities of phosphate accelerate algae and plant growths in natural waters, thereby enhancing eutrophication and reducing oxygen levels in the water. The data showed that the results of the phosphate analysis were very low during the period under study.

The highest phosphate concentration was recorded in 2015 with an average value of 10.9mg/L (Figure 15) and this was far below WHO's concern that phosphate concentrations beyond 100mg/L is considered as excess and may interfere with coagulation processes in water treatment plants (WHO, 2011). Results from Figure 15 also demonstrated that phosphate contributed very little to eutrophication (algal production) on the water surface as indicated by Fadiran et al (2008), that too much phosphates concentration in water results in high rate of eutrophication.

Nitrate

The Nitrate concentration in the Weija reservoir was found to be in the acceptable limit (10mg/L) i.e. between the ranges of 0.02mg/L to 4.9mg/L within the years chosen for the study. The highest Nitrate value (4.9mg/L) was recorded in 2015 with the least recording (0.02mg/L) in 2012. It could also be observed that the Nitrate level started declining from 2008, through to 2013, after which there was a drastic increase in 2015 and a sudden decrease in 2016. This pattern of occurrence is similar to that of Phosphate which also ends up in water through human activities and agricultural runoffs.

The low recordings of nitrate for the 14 years indicated that water from the Weija reservoir is somehow free from bacterial contamination as stipulated by WHO (2007), that high levels of nitrate in drinking water is often associated with the simultaneous presence of bacterial contamination. Also, consumers of water from the Weija reservoir are free from a condition known as methaemoglobinaemia, which according to WHO (2006), is when blood lacks the ability to carry sufficient oxygen to the individual body cells which may cause the skin and veins to appear blue, and this condition happens when nitrate is converted to nitrite and reacts with iron in the haemoglobin of the red blood cells.

Ammonia

Ammonia is not of any direct relevance to health at levels within which they occur in water bodies, and no health-based guideline value has been proposed. However, ammonia does react with chlorine to reduce free chlorine and to form chloramines which contributes to odour and taste problems in water (WHO, 2011). The ammonia content in the Weija Reservoir had very low readings as compared to the World Health Organization's standard of 1.5 mg/L. The record showed that in 2012, the level of ammonia in the water sample was 0.6 mg/L which represents the highest recording year while in 2015 and 2016, ammonia recordings were either null or very insignificant. There was an increase in ammonia concentration in 2003 and 2004 while its content in the water started declining in 2008 through to 2011. Again, there was a drastic increase from 0.06mg/L in 2011 to 0.6mg/L in 2012. The sudden increase could be linked to increased industrial and agricultural activities around the water course since concentration of ammonia in water could come from industrial, domestic, agricultural pollution; mainly from fertilizers and organic matters.

Although the highest average content was recorded in 2012, ammonia content in water decreased tremendously in the years 2013, 2015 and 2016.

Colour, Turbidity and Iron

Colour in drinking-water is generally due to the presence of suspended and dissolved particles. Colour is also intensely influenced by the presence of metals such as iron. The colour patterns from 2002 – 2004 and 2007 – 2011 were highly influenced by iron concentrations in the water; as the level of iron increased, the colour level also increased. Thus, the colour of the water was positively related to the presence of iron.

There were some few instances where the colour was highly influenced by the presence of high level of Total solids. There was a rise in the colour from 106 TCU in 2004 to 118 TCU in 2006 being as a result of increased concentrations of the Total solids in the reservoir. Noticeably, there was a decrease in colour in the 2012 – 2013 periods and a sudden rise in the 2015 – 2016 period; these recordings were influenced by the patterns of Iron and Total solids respectively. It was realized that, average levels of colour of water in the Weija Reservoir was very high as compared to the World Health Organization's guideline of 15 TCU. This was evident when in 2015 the least colour level was recorded as 68 TCU. Though the values were beyond the WHO's set guideline, it was seen from the results that the colour levels kept improving from 2011 until 2016 when it suddenly rose to 84.1 TCU due to high presence of Total solids. The fluctuation was as a result of the various activities around the river which influenced the presence of Iron and the Total Solids concentrations in the water.

The turbidity levels in the Weija Reservoir were very appalling as the values recorded were all beyond the WHO set guideline of 5 NTU (Nephelometric Turbidity Unit). Figure 18 showed a sudden increase in the average turbidity from 18.9 NTU in 2002 to 25 NTU in 2003, with this being the highest value for the study period. The least turbidity value was recorded in 2013 which was 7.4 NTU. After the sweeping rise in 2003, there was an improvement in the turbidity values over time. High levels of turbidity throughout the 14 years showed that there were too much particulate materials as indicated by Putz (2003) that particulate materials such as clay or silt, plankton and finely divided organic matter increase the level of turbidity of water.

Though the quality of the water in terms of turbidity had been improving since 2003, it is very essential to pay much attention to it as it contributes extra cost to treatment of the water. It also affects light available to aquatic organisms as it is indicated by Stanistski et al. (2000) that high level of water turbidity result to high degree of light scattering by suspended particles such as clay or silt. The turbidity was as a result of the presence of Total Iron and Suspended particles. It was seen from Figure 18 and Figure 23 that the pattern of occurrence of the Total Iron concentration in the water was the same as that of the turbidity. The turbidity was increasing with the increase in Iron and vice versa from 2002 – 2008. During this period, the turbidity was highly influenced by the Total Iron. The pattern changed for the subsequent years due to several factors including the presence of

Suspended Solids. Suspended Solids was the major contributor to the turbidity from 2010 through to 2016.

The presence of iron in water has no direct health impact on consumers, but it can be a worrying chemical in water supplies. When ferrous iron oxidizes to ferric iron, it gives an objectionable reddish-brown colour to the water when exposed to the atmosphere (WHO, 2011). The dissolved ferrous iron gives water a displeasing metallic taste. The presence of Iron in water promotes the growth of "iron bacteria" which deposits a reddish brown or yellow slime that can result in an offensive odour. Figure 23 indicated that all the study years recorded Iron concentrations within the WHO standard of 0.3mg/L with the exception of 2012, which exceeded the WHO guideline with an average Iron concentration of 1.7mg/L. Iron concentrations beyond 0.3mg/L stains laundry and plumbing fixtures (WHO). The presence of iron in the reservoir may be due to weathering of iron bearing minerals and rocks such as carbonates and iron clay minerals.

pH

Though pH has no direct health impact on water consumers, it is one of the most significant water quality parameters, as the solubility and bioavailability of chemical constituents and heavy metals in water depend on it. The pH levels of the raw water samples within the study period were found to be in the acceptable range (6.5 – 8.5) set by the WHO. The highest pH value recorded was 7.9 and this was recorded in 2002, 2004 and 2015 while the least pH was recorded in 2006, 2007, 2008 and 2011, with an average of 7.5. Although pH levels were high throughout the years, it could be attested from Figure 20 that all yearly recordings for pH fell within the optimum pH range (6.5 – 8.5) which is said to reduce the solubility of heavy metals in water hence making it less toxic to aquatic lives (Alabaster & Lloyd, 1980).

Temperature

Temperature is the degree of hotness or coldness of the water. Cool water is usually more palatable than warm water. However, high water temperature increases the growth of microorganisms and may increase problems related to odour, taste, corrosion and colour (WHO, 2011). The temperature is affected by the presence of suspended solids in the water; the solids absorb sunlight which further heats the water. The presence of the suspended solids may be as a result of the removal of vegetation (due to illegal mining at upstream) near the water source which often results in increased erosion and increased amounts of sediments in the water. Removal of vegetation around the river will increase the heating of the water surface by sunlight. The temperature of the water was between the ranges of 25.6 - 28.7^{o}C. Though temperature within this range reduces the solubility of oxygen in the river, it improves the efficiency of disinfection during water treatments as reactions occur more quickly. At lower temperatures, longer contact times or higher concentrations of chemicals are required for disinfection. There are no guidelines for temperature.

Sulphate

The data showed that sulphate concentration was far below the proposed guideline of 500mg/L by the WHO. Though it is of no health concern, elevated sulphate levels together with chlorine bleach can make cleaning of clothes very difficult. Excessive sulphate may cause laxative effect and can promote the growth of sulphur-oxidizing bacteria with effects similar to those of iron bacteria.

The highest Sulphate concentration was recorded to be 19.4mg/L in 2003 with the least value, 8mg/L, recorded in 2002. Though the values were far below both the WHO (ma. 500mg/L) and Ghana Standard Board's guideline value (max. 250mg/L), there were variations throughout the study period. The presence of the Sulphate can be attributed to natural occurrences.

Fluoride

Fluoride is very vital in drinking-water in order to shield human tooth against cavities (WHO, 2011) but it can be harmful when it exceeds its limits. The fluoride concentrations in the Weija Reservoir for the study period were observed to be within the WHO's guideline value of 1.5 mg/L. It was observed from Figure 24 that, there were insignificant fluoride concentrations in the 2002, 2012 and the 2016 study years. The Figure showed that the highest value was recorded in 2015 with an average concentration of 0.5 mg/L. However, it was within the acceptable limit. This makes the water good in terms of fluoride occurrence as concentrations above 1.5mg/L has higher risk of dental fluorosis with which increasingly higher concentrations can lead to risks of skeletal fluorosis (WHO).

Total Solids (Suspended Solids and Dissolved Solids)

Total solids, TS, are a sum total of all the suspended and dissolved solids in a sample of water. Natural water carries many dissolved and un-dissolved solids. The presence of solids in water affects its quality. The analysis indicated that the solids in the water contributed highly to the occurrence of turbidity, colour, and change in temperature.

Though the WHO and GSBA have no guideline values for suspended solids, the GSBA advices that water for drinking should have no amount of suspended solids. Its presence was the reason for the high turbidity occurrence in the water from the Weija Reservoir as demonstrated by Figure 18. The suspended solids in the Weija reservoir started declining after 2007, through to 2012, after which its concentration started increasing from 2013 to 2016. This indicated that there had been increased human activities around the water source within the last three years and this calls for maximum attention. The suspended solids end up in the water through run-offs from upstream forests, farm lands and waste water from anthropogenic activities.

Total dissolved solids (TDS) comprise organic matter and inorganic salts (principally magnesium, calcium, sodium, chloride, bicarbonate and sulphates) that are dissolved in water. Figure 27 gives an account on the level of TDS in the water samples which were recorded from 2002 to 2016. It was observed from the figure that the level of total dissolved solids in the water throughout the 14-year period was very low, recording 196.8 mg/L as the highest average value for the study period. This level of total dissolved solids makes the water from the Weija reservoir of good quality and so therefore palatable as indicated by WHO(2011), that water is termed to be of good palatability if its total dissolved solids are less than 600 mg/L.

Thus, the taste and the overall health of the water will be good as the TDS values are far below 600 mg/L. The total dissolved solids in drinking-water originate from urban runoff, sewage, industrial wastewater as well as natural sources (WHO, 2011). All the recordings from the years under study fell within the WHO guideline values (500-1000mg/L).

Total Hardness (Calcium and Magnesium)

The amount of dissolved magnesium and calcium in water sums up to the total hardness level of water (USGS, 2016)**.** The average levels of hardness in the water were within the acceptable limit of 500mg/L. It was also observed from Figure 28 that the level of hardness in the water was increasing from the last eight years (2008 - 2016) and this calls for much attention as it is gradually getting close to 200mg/L. According to WHO (2011), water with hardness level above approximately 200 mg/L may lead to the deposition of scale in treatment works, thanks and distribution systems.

The pattern of occurrence of total hardness was influenced highly by the presence of calcium in the water. Inferences from Figure 28 and Figure 29 indicated that hardness was increasing with increasing calcium concentrations and vice versa. Though, magnesium was present, it was in smaller quantities and also fell within WHO expected guideline value of 30mg/L. Such levels of magnesium are associated with increased vascular reactions, endothelial dysfunction and decreased insulin sensitivity as indicated by the WHO (2009).

Calcium was the principal contributor to the hardness of water from the Weija Reservoir. The calcium concentrations fell within the WHO guideline value of 50mg/L except for the year 2007 which recorded 158.4mg/L. This was a major factor for the increase in the total hardness of the water for the last 8 years and signals a possibility of soap consumption during washing.

From the data, it was deduced that, the total hardness of the water in the Weija reservoir was highly influenced by the presence of calcium and magnesium ions which could occur naturally from weathering of sedimentary rocks, magnesium bearing minerals and calcium-bearing minerals of the river's basin.

Discussions on Relationships between Urbanization and Quality of Water

Relationships between Phosphate, Nitrate, Ammonia and Urbanization

It was deduced from Figure 15, Figure 16 and Figure 17 that recordings of phosphate, Nitrate and Ammonia contents in water from the Weija reservoir had very low recordings with the exception of Phosphate in the year 2015, which had a very high recording of 11mg/L.

The low value recordings of the above parameters over the years was as a result of decreased in farming activities in general or a decreased/proper means of fertilizer application and proper liquid waste management of the increasing population in the DRB. From Table 6, it was deduced that on a yearly basis, the population in the DRB increased by 22,254 yet Phosphate, Nitrate and Ammonia kept on attaining low readings.

Low readings from 2002 to 2007 by phosphate, Nitrate and Ammonia (Figures 15, 16 and 17) could be related to the decrease in farm lands within the Densu basin from 44.2 sq. km in 2002 to 5.1 sq. km in 2007 (Table 8). On the other hand, although 'built-ups' such as houses and industries kept on increasing in 2002 through 2007 to 2016 (Table 8), it was believed that industrial and household water wastes were managed properly. For example, by 2007, 11.43 sq. km of farm lands in 2002 had been converted to build-ups (Table 9). In continuation, by the year 2017, about 71.43 sq. km of lands from other land use/cover excluding water (in the year 2007) had been converted into farm lands (Table 10). From Table 12 below, 125 representing 78% of farmers affirmed to have increased the size of their farmlands after 2007, yet the analysis of the water in the reservoir recorded low levels of ammonia, phosphate and nitrate in subsequent years and this indicated the possibility of proper means of fertilizer application by farmers. The above discussions confirmed the assertion made by USESB (2003) that Phosphates, Nitrate and Ammonia are often at minimal values if proper industrial and household discharge, fertilizers and pesticides applications are made.

Table 12: Farmers Views on Increase in Size of Farmlands within Selected Years

Years	Percentage
Before 2002	30
2002-2007	16
After 2007	54
Total	100

Source: Field survey, Sampson (2017)

From the above discussion, it can be concluded that urbanization within the DRB had contributed less of Phosphate, Nitrate and Ammonia into water from the Weija reservoir.

Relationships between Turbidity, Colour and Urbanization

Turbidity and colour of water are the first two parameters that a person will check before he/she takes in any water. From Figure 18, and Figure 19, it was deduced that the average recordings of turbidity and colour throughout the years were above the maximum limit of 5NTU and 15TCU respectively. These high readings of Turbidity and Colour of water from the Weija Reservoir could be attributed to the persistence of stone quarrying, sand mining and galamsey activities that took place at the north eastern part of the basin. The increase in such activities could be linked to the consistent increase in human population within the basin from 1,054,915 in 2002 to 1,200,457 in 2007 and 1,366,483 in 2016 (Table 6).

These activities produce silt and clay which tend to reduce transparency and clarity of the water as also indicated by Putz (2003) that clay, silt, finely divided organic matter, plankton or other microscopic organisms from activities of urban areas reduce transparency of water.

Responses from respondents-

> "*60% of the respondents gave a submission that as at 2002, water from the Densu river at large was suitable for drinking while question on water Suitability for Drinking as at now revealed that 90% of the respondents agreed that the water as at the current time (2016), was not suitable for drinking*".

The above discussion gives a vivid declaration that urbanization within the DRB had been the cause of high turbidity and bad colour content of the Weija water.

Relationships between pH and Urbanization

The analysis from Figure 20 shows that although some years recorded high values of pH, it was revealed that all yearly recordings for pH fell within the optimum pH required range of 6.5–8.5 (as per WHO guideline value).

The low pH value of water from the Weija Reservoir is as a result of the geology and soil nature of the catchment. Rocks such as granite in the middle section of the basin are a contributing factor to the low level of pH in the water from the lake as indicated by Stephanie (1998).

Relationships between Temperature and Urbanization

The temperature of streams and rivers attain higher recordings whenever vegetation at their banks are cleared leading to direct sunshine hit. Figure 21 revealed that all average recordings for the years were high although WHO as well as GSB has no guideline values.

Urbanization within the basin propelled this effect since it exerted great amount of pressure on clearing vegetation within the river basin for accommodation and industrial purposes. For example, in Figure 8, closed and open forests lost 605.0442 sq.km (38%) and 281.13sq.km(18%) of land area respectively to other land use/cover types (farmland, water, Bare land and built ups) through 2002 to 2007. It was also revealed from Figure 11 that 'closed and open forests' lost 762.86 (41%) and 443.27 (24%) of land area respectively between the years of 2007 and 2017.

It is therefore believed from the above discussions that the high recordings of temperature from 2002 to 2016 is as a result of the increase in farmlands, bare lands and 'built ups' over the years which are as a result of the continuous increase in population within the DRB.

Relationships between Sulphate and Urbanization

Sulphate (SO_4^{2-}) is a combination of sulphur and oxygen. Readings from Figure 22 showed that all average levels of sulphate of raw water from 2002 - 2016 were within the expected limit established by the WHO (Max. 500mg/l).

The introduction of sulphate from human activities within the DRB was very little. Although population, built up and farming activities kept on increasing from 2007 through to 2017 (Table 8), sulphate levels kept on remaining very low. This is in disagreement with an assertion made by Okeola et al. (2010) that the increase in human population and activities such as domestic and industrial outings end up increasing sulphate concentration in water.

The above discussion can therefore help to conclude that sulphate concentration in the Weija Reservoir was of a more natural introduction than as a result of urbanization, and this is in written in a consensus by Silberberg (2000) that sulphate occurrence in water often happens naturally through water runoffs from many soil and rock formations.

Relationships between Iron and Urbanization

Since iron is seen to be in abundance among the entire elements in the earth's crust, next to aluminium (Antonovics, Bradshaw, & Tuner 1971), the discharge of mining waste, acid mine drainage from the Birimian formation in the East Akim district and stone mining at the upper section of the DRB especially in Koforidua and Nsawam will consequentially increase iron levels in the Densu river.

From Figure 23, it was deduced that iron recordings fell within the WHO's established value of (0.3mg/l) except recordings made in 2007. Since it was noticed that such recordings were not far from either attaining or exceeding the WHO max value of 0.3mg/l, it confirmed that urbanization could have an influence on the iron content in the Weija Reservoir through mining and stone quarrying activities.

Relationships between Fluoride and Urbanization

From Figure 24, it was noted that fluoride recordings throughout the 14-year period fell within the established guideline value of WHO, which is (1.5mg/L). The higher readings made in 2003, 2004, 2007 and 2015 is an indication of an increase in activities such as bricks, tiles and ceramics making within the DRB as indicated by the WHO (1984), these activities are among the important sources of fluoride. Urbanization variables such as population must have influenced these higher recordings as the consistent increase in population with an average of 22,254 in those years could have resulted in more people demanding bricks, tiles and ceramics for constructions.

Although the population occupying the DRB kept on increasing, none of the years recorded the maximum guideline by the WHO (1.5mg/L).

Relationships between Total Solids (Total Suspended Solids and Total Dissolved Solids) and Urbanization

With a population of 1,054,915 in 2002, water from the Weija Reservoir recorded the lowest level of TS (115.4mg/L) while the highest level of TS (210.9mg/L) was recorded in the year 2016 with a population of 1,366,482 (Figure 25 and Table 8). The more the population in the DRB increases every year by the addition of 22,254 people, the persistent increase in built ups through the years (Table 8) and the tremendous increase in farm lands after 2007 (Table 8) resulted in a consistent increase in the levels of TS in the water from the Weija Reservoir after 2002.

A comparison of Figure 27 (TDS) and Figure 26 (TSS) against Figure 25 (TS) showed very clearly that TS levels in the Weija Reservoir were greatly influenced by both TSS and TDS. Reasons given by respondents on pollution of the Densu River revealed that 45% were of the view that improper waste disposal was the major cause of pollution of the Densu River.

Also, increased small scale mining, sand mining and stone quarrying along the Densu River were stated as the second highest source of pollution. This is in agreement with what Ghrefat and Yusuf (2006) stated, that activities such as small scale mining discharge waste water as well as run-off of silt and clay particles which result in high level of TSS in a nearby water body.

Table 13: Reasons for Water Pollution

Response	Percentage (%)
Improper waste disposal	45
Increased sand mining and stone quarrying	30
Increased cattle rearing	10
Increased farming activities	15
Total	100

Source: Field survey, Sampson (2017)

From the above discussions, it can be deduced that people living within the Densu basin were not properly disposing off their wastes which resulted to the deposition of these wastes into the river body after runoff, thereby making the river a refuse receptacle. This would therefore lead to a laudable assertion that urbanization within the DRB for the past 14 years has had much influence on Total Solids in water from the Weija Reservoir.

Relationships between Total Hardness (Calcium and Magnesium) and Urbanization

Calcium carbonate and magnesium salt contents are basically responsible for causing hardness in water**.** Recordings from Figure 28, Figure 29 and Figure 30 showed that levels of Total hardness, calcium, and magnesium in water from the Weija Reservoir were very insignificant throughout the years. Although 120mg/L level of hardness was recorded in the year 2016, it was below the level established by the WHO which is 500mg/l.

From Table 14, 92% of the respondents agreed that water from the Densu River is suitable for domestic purposes while the remaining 8% disagreed. This result gave a close affirmation to what Figure 28, Figure 29 and Figure 30 displayed on hardness, calcium and magnesium respectively.

Table 14: Water Suitability for Domestic Purposes

Response	Percentages (%)
Yes	92
No	8
Total	100

Source: Field survey, Sampson (2017)

Although after 2002, Total hardness increased consistently from 2003 through to 2016, it could be concluded that the hardness of water from the Weija Reservoir was not much influenced by urbanization that happened within the DRB over the 14 years. This was such that hardness remained very low, even below the minimum value established by WHO although urbanization measures such as population, increased from 1,054,915 in 2002 to 1200457 in 2007 and 1,366,483 in 2016.

CHAPTER SIX

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Introduction

This chapter provides a summary of the study and conclusions that were drawn from the results and the discussions. The chapter also gives some recommendations concerning activities to be undertaken in the DRB and recommended that the quality of water from the Weija Lake be monitored.

Summary

The study aimed at revealing existing relationships between urbanization in the Densu River Basin and the quality of water of the Weija Lake using Landsat imageries of 2002, 2007 and 2017, population figures for the respective years and yearly averages of selected water quality parameters. The objectives involved mapping of land use-land cover types within the DRB, assessing changes in land use/cover types of the area, analyzing the trend in quality of raw water of selected parameters over the 14-year period and finally, establishing existing relationships between the rate of urbanization and the quality of raw water in the study area.

The land classification maps of 2002, 2007 and 2017 were derived from the United States Geological Survey Classification System for Land use/cover types. The land classification produced six classes namely; Water, Bare land, Farm land, Built up, Open forest and Closed forest. The changes in the land use/cover classes during the study were detected using the land classification maps of 2002, 2007 and 2017.

Water quality parameters involved in the study comprised all parameters that had consistent recording throughout the 14-year period (2002-2016). Such parameters included Phosphate, Nitrate, Ammonia, Turbidity, Colour, PH, Temperature, Sulphate, Iron, Fluoride, Total Solids, Suspended Solids, Total Dissolved Solids, Total Hardness, Calcium and Magnesium. The yearly averages of recordings of the said parameters were used for the study and results were presented in graphs.

Main Findings

Based on the specific objectives of the study, the main findings are as follows:

The land classification maps revealed that between 2002 and 2007, closed and open forests were the most predominant land use/cover types in the entire river basin followed by built up and bare land. However, between 2007 and 2017, built up area augmented consistently to exceed open and closed forests as the second most dominant land use/cover type.

The drift analysis of the River Densu Basin area revealed that, built up, farm land and open forest experienced an increment while bare land, closed forest and Water experienced a fall over the 14-year period.

Basically, the transformation of the area covered by the land use/cover classes, as in the bare land, closed and open forests between 2002 and 2007 indicated a depletion of land area in these land use/cover types. Likewise, the transformation of the area covered by the land use/cover classes, in the same period for Built up indicated an encroachment of this land use type into other land use/cover types. Thereby, an increase in urbanization during this period, gave rise to an extensive deforestation of the Closed and Open forests.

Between 2007 and 2017, there was extensive depletion of land use/cover for the closed forest, bare land and the open forest signifying a transformation of land from these land use/cover types into other land use/cover areas. On the contrary, the increase in the land use/cover areas of built up and farm lands indicated that substantial amount of other land use/cover types had been encroached. As a result, the intensification of built up during this period, gave rise to urbanization and a fall to the forest zones (closed and open forest) in relation to deforestation.

With regards to trend analysis of water quality parameters, it was observed that the results for phosphate, nitrate, ammonia, sulphate, iron (except for the year 2012), fluoride, suspended solids (expect for the years 2004, 2015, and 2016), total dissolved solids, total hardness, calcium (except for the year 2007) and magnesium analysis fell within the WHO guideline values. Likewise, the results for pH analysis fell within the ranges of the WHO standards. However, that of turbidity and colour recordings fell beyond the WHO standards. Temperature recordings on the other hand, fell between the ranges of 25-28 degrees.

In terms of existing relationships between urbanization and the quality of water parameters such as phosphate, nitrate and ammonia, their contents in water from the Weija reservoir had very low readings. These low readings were as a result of the decrease in farm lands within the Densu basin. By the year 2017, about 71.43 sq. km of lands from other land use/cover excluding water had been converted into farm lands. As an accentuation, 78% of farmers indicated to have increased the size of their farmlands after 2007, yet low recordings of ammonia, phosphate and nitrate in subsequent years.

From the existing relationship between urbanization and the quality of water parameters such as turbidity and colour, it was deduced that average recordings of turbidity and colour throughout the years were above the maximum limit of 5NTU and 15NTU respectively. This was attributed to the persistent stone quarrying, sand mining and galamsey activities in relation to consistent increase in human population within the river basin.

The relationships between pH and urbanization revealed that, all the yearly recordings for pH fell within the optimum pH required range of (6.5–8.5; as per WHO guideline value). Rocks such as granite in the middle section of the basin might be a contributing factor to lower pH in water from the lake.

In the case of temperature, it was revealed that all average recordings for the years were above the minimum value established by the WHO. The temperature of streams and rivers increase whenever vegetation at their banks is cleared leading to direct penetration by sunshine. Urbanization within the basin influenced this effect since it propelled the clearance of vegetation at the banks of the river.

Also, in the case of sulphate, all average levels of sulphate of raw water from 2002-2016 were within the expected limit established by the WHO.

Although population, built up and farming activities kept on increasing from 2007 through to 2017, sulphate levels still remained very low. This is in a complete disagreement with the assertion made by Okeola et al. (2010) that increase in human activities such as domestic and industrial discharge end up increasing sulphate concentration in water.

Relationships between Iron and urbanization showed that, discharge of waste from mines, acid- mine drainage from the Birimian formation in the East Akim district and stone mining at the upper section of the DRB especially in Koforidua and Nsawam consequentially added some level of iron to the Densu River. Hence, it is logical to say that mining and stone quarrying activities had a role to play in iron concentration in the Densu River.

Relationships between Fluoride and urbanization revealed that, higher readings made in 2003, 2004, 2007 and 2015 were an indication of increase in activities such as bricks, tiles and ceramics making within the DRB as indicated by WHO (1984). Urbanization in relation to population increase in such years would have been an influence to these higher recordings as bricks, tiles and ceramic products were in a high demand.

In the case of Total solids (total suspended solids and total dissolved solids) and urbanization, the lowest level of TS (110mg/L) was recorded in 2002 while the highest level of TS (200mg/l) was recorded in the year 2016. As an accentuation, 45% of the respondents were of the view that improper waste disposal is the major cause of pollution of the Densu River. It was also clear that TS levels in the Weija Reservoir is greatly influenced by TSS than TDS.

Existing relationship between urbanization and total hardness (calcium and magnesium) showed that, levels of calcium hardness contributed significantly whilst magnesium hardness in water from the Weija Reservoir was very insignificant throughout the years. Although 120mg/l of total hardness was recorded in the year 2016, it was below the level established by the WHO which is 500mg/l.

The study showed that the perceived major causes of land use/cover classification and transformation in the River Densu Basin are associated with urbanization growth as socio-economic activities such as building, road construction, utility service expansion, and farming and so on kept increasing over this 14-year period. Most of these activities had taken different forms during the course of time, and had posed significant negative effects in the chemical and physical composition of water parameters present in the Weija Lake.

Conclusions

Based on the results and findings, this study concludes that land use-land cover types in the Densu River Basin are water, bare land, farm land, built up, open forest and closed forest. Among these, there has been an increase in built up, farm lands and bare land while open forest, closed forest and water have decreased substantially over the 14-year period. This implies that land use-land cover changes and transformation in the DRB is as a result of an increase in urbanization growth and its undertakings.

Also, this study can conclude on the basis of the results and findings that, most of the water quality parameters results for the Weija Lake fell within the WHO standards during the 14-year period.

In a similar development, this study concludes based on the results and findings that parameters such as turbidity, colour, pH, temperature and total solids were highly influenced by urbanization while phosphorus, nitrate, ammonia, magnesium, calcium, total hardness, fluoride, iron and sulphate were less influenced though urbanization increased over the 14 years. This implies that water from the Weija Lake can be termed to have been of high quality putting into consideration phosphorus, nitrate, ammonia, magnesium, calcium, total hardness, fluoride, iron and sulphate since they fell within WHO guidelines, this effect gives a signal of resource sustainability by the population within the catchment. On the other hand, sustainability of the weija reservoir by the people within the river Densu catchment was seen with little concern as the water can be termed to have been of less quality over the 14 years by considering parameters such as turbidity, colour, PH, temperature, suspended solids and total solids since their recordings were often above WHO guidelines.

On the whole, this study was able to map land - use-land - cover types and changes within the Densu River Basin for the years 2002, 2007 and 2017, analyze the trend in quality of raw water and establish a relationship between the rate of urbanization and quality of raw water over the 14-year period.

Recommendations

Based on the main findings and conclusions drawn from the study, the following recommendations are made. These recommendations are to ensure that sustainability of the quality of water from the Weija reservoir is achieved through clean integration of social, environmental and economic development as emphasized in the definition giving by the Bruntland commission.

There is the need for Densu River Authority to increase the size of community stakeholders in the management of the Densu River Basin. Also, management and monitoring structures should be established at community levels. This would ensure a strong sense of ownership and belonging by the local communities.

It will be very judicious for Densu Basin Board, which was established by the Water Resource Commission (WRC) in 2004 with the charge of regulating activities in the DRB, to strengthen and continue its monitoring of land use/cover types as they are being influenced by persistent pressure from urbanization and anthropogenic activities which have resulted in encroachment of the Densu River.

Agricultural departments at the various district and municipal assemblies within the DRB are to educate farmers on clean methods and technologies for farming so as to ensure that the water body maintains its low recordings of agricultural related parameters such as phosphate, nitrate and ammonia.

In addition, sanitation departments at the various municipal and district assemblies are to ensure that proper measures are put in place to regulate and promote proper solid wastes disposal. This, when taken seriously, will result in the low recordings of Turbidity, Colur and Total Suspended Solids from the Weija Lake.

Stakeholders of DRB such as the Densu River Authority (DRA), the Water Resource Commission (WRC), the Ghana Water Company Limited (GWCL), Weija Head Works (WHW) and the District Assemblies should ensure that tree planting activities that took place within the Weija reservoir catchment in 2007 is revived and strengthened. This will save the water body from too much suspended solids during runoff since available trees would serve as blockages.

It would be very rational and convivial if the Ministry of Works and Housing adopts and makes pungent policies and technological strategies to change the style of building and its expansion vertically instead of horizontally. This, in prospect, will slow down the rate at which 'built up' is extending in the area; thereby, discouraging encroachment into close and open forests that tend to protect the water in many ways.

Suggestions for Further Research

Further study or research can focus on assessing institutional commitments on preventing land encroachment within the DRB.

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APPENDICES

APPENDIX A

UNIVERSITY OF CAPE COAST

DEPARTMENT OF GEOGRAPHY AND REGIONAL PLANNING

INTERVIEW SECHEDULE FOR HOUSEHOLDS

Dear respondent, this instrument has been designed to seek your assistance on the topic; "Urbanisation and Quality of Raw Water: a Case Study of the Weija Reservoir, Ghana". It is strictly for academic purpose and therefore all information provided shall be treated with maximum caution and confidentiality. All personal data provided shall be treated collectively and not on personal levels.

SECTION A: Background Information

This section collects demographic information on the respondents.

Please tick [√] **where applicable.**

1. Community…………………………………………………………….
2. Sex a. Male [ ] b. Female [ ]
3. Age at last birthday (Please specify) ……………………
4. Education: a. Primary [ ] b. Middle School/JHS [ ] c. Secondary/SHS [ ]

   d. Post-secondary/Tertiary [ ] e. No formal education [ ] f. Other please specify…………
5. Occupation………………………………………………………………

SECTION B: Benefits/activities community derive from the environment

This section investigates the benefits/activities that the community derives from the environment. Please tick [√] as many as are applicable.

6. What is/are the benefits/activities derived from this basin?

Benefit/Activity	Goods/Use	Tick	Season
Harvesting of natural herbaceous vegetation	Food		
	Fuel		
	Building Material		
	Mulching Material		
	Craft material		
	Medicines		
Agriculture	Food		
	Fibre/other		
Mining	Clay		
	Salt		
	Gravel		
	Minerals		
	Sand		
Water collection/use	Domestic use		
	Irrigation water		
	Water for livestock		
	Industrial water		
Fisheries	Fin fish		
	Shell fish		
	Other		
Human Settlement	Housing		
	Industrial		
Hunting	Meat		
	Skin		
Livestock Grazing	Goat		
	Sheep		
	Cow		
Others			

SECTION C: Issues on quality of water and urbanization

This section looks at respondents' perception of quality of water and urbanization within the river basin.

7. Do you agree to the fact that urbanization has increased in the basin?

a. yes b. no

8. When did you increase the size of your farmland?

a. Before 2002 b. 2002-2007 c. after 2007

9. Was water from the river suitable for drinking as at 2002?

a. Yes b. No

10. Is water from the river suitable for drinking as at now?

a. Yes b. No

11. Is the water suitable for domestic purposes?

a. Yes b. No

Please rank the following options from 1 to 4 with 1 being the highest and 4 being the lowest.

11. Which of the urbanization indicators has increased tremendously over the13 year period?

Indicator	**Rank**
Agriculture activities	
Industries	
Settlements	
Population	

9. What changes have you observed in quality of water in your area over the last 13 years?

i. ……………………………………………………………………

ii. ………………………………………………………………………...

iii. ………………………………………………………………………

11. If your answer to the above question is negative, then what has accounted for it?

i. ……………………………………………………………………………….

ii. ……………………………………………………………………………….

12. Do people use the river as a dumping site for refuse?

a. yes b. no

13. Are you aware of any water protective organization in your community?

Aware [ ] Not aware [ ] Not sure [ ]

14. If aware, name them:

i ……………………………………………………………..

ii ……………………………………………………………..

15. In your opinion, what are some of the activities that pollute the river?

i. ……………………………………………………………………………

ii. ……………………………………………………………………………

iii. ……………………………………………………………………………..

APPENDIX B

DETERMINATION OF SAMPLE SIZE

Calculations

$$n = \frac{(1.96)^2(0.8)(0.2)}{(0.05)^2}$$

$$n = \frac{(3.8416)(0.16)}{0.0025}$$

$$n = \frac{0.614656}{0.0025}$$

$$n = 245.86$$

$$n = 246$$

APPENDIX C

WATER QUALITY PARAMETERS AND THEIR RESPECTIVE GUIDELINE VALUES BY WHO AND GSBA

Parameter	Unit	WHO. (2011). Guidelines for drinking water quality. (4th, Ed.)	Ghana Drinking Water Standards, FDGS 175-1:2013
Phosphate	-----	--------------	………………
Nitrate	mg/L	Max. 10	Max.50
Ammonia	mg/L	Max. 1.5	………………
Turbidity	NTU	Max. 5	Max.5
Colour	TCU	Max. 15	Max. 5
pH	-------	6.5-8.5	6.5-8.5
Temperature		------------	-----------
Sulphate	mg/L	Max.250	Max. 250
Iron	mg/L	Max. 0.3	Max. 0.3
Fluoride	mg/L	Max. 0.3	Max. 1.5
Total Solids	mg/L	Min. 100 – Max. 150	……………

Total Suspended Solids	Mg/L	Min. 8.2 - Max. 12	
Total Dissolved Solids	mg/L	Min. 500 - Max. 1000	Max. 1000
Total Hardness	mg/L	Max. 500	Max. 500
Calcium	mg/L	Max. 75	Max. 75
Magnesium	mg/L	Max. 30	Max. 30

APPENDIX D

INTRODUCTORY LETTER

UNIVERSITY OF CAPE COAST
COLLEGE OF HUMANITIES AND LEGAL STUDIES
FACULTY OF SOCIAL SCIENCES
DEPARTMENT OF GEOGRAPHY & REGIONAL PLANNING

Our Ref: GRP/G.4^A/16/Vol.1/136

Your Ref:

UNIVERSITY POST OFFICE
CAPE COAST, GHANA
WEST AFRICA

24th April, 2017

………………………………………………
………………………………………………
………………………………………………
………………………………………………

Dear Sir/Madam,

LETTER OF INTRODUCTION
TO WHOM IT MAY CONCERN

The bearer of this letter, Mr. Lord Ebow Sampson, is an MPhil. Student of the Department of Geography and Regional Planning, University of Cape Coast.

As a requirement of his programme, he is undertaking a research project on the topic: ***"Urbanization and Quality of Raw Water: A Case of The Weija Reservoir".***

We shall therefore be very grateful if your institution could assist him with any information that would be relevant to the research.

Thank you.

Yours faithfully,

Dr. Simon Mariwah.
HEAD

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