EXPLORING THE COMPETING USES OF WATER IN THE CONTEXT OF CLIMATE VARIABILITY AND CHANGE IN THE LAWRA DISTRICT

BY

ABU, THELMA ZULFAWU

(10506932)

THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF MPHIL ENVIRONMENTAL SCIENCE

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DECLARATION

I, ABU THELMA ZULFAWU, the author of this thesis, hereby declare that the submission of this work on "EXPLORING THE COMPETING USES OF WATER IN THE CONTEXT OF CLIMATE VARIABILITY AND CHANGE IN THE LAWRA DISTRICT" towards a partial fulfilment of my MPhil Environmental '

Science Programme at the Institute for Environment and Sanitation Studies. College of Basic and Applied Science, University of Ghana, Legon was entirely done by me under the guidance of my supervisors. This work has never been accepted for the award of any other degree in any University, except for the references which are duly acknowledged in the work presented:

……………………………......... ……………………………..........

ABU THELMA ZULFAWU Date

(Student)

This thesis has been presented for examination with our approval as Supervisors:

…………………………………. …………………………………..

Prof. Chris GORDON Date

(Principal Supervisor)

....

Dr. Adelina Mensah Date

(Co-Supervisor)

ABSTRACT

A highly diverse set of user groups depend on freshwater resources and services for domestic use, agricultural and industrial purposes as well as ecosystem functioning. Many freshwater supply sources are already over allocated, suffer degraded water quality, and are often not in sufficient condition to support life. The steps towards poverty reduction that targets sustainable development will be jeopardized if improved water resources management and effective storage measures are not instituted.

A mixed method survey was conducted in four randomly selected communities in the Lawra district of the Upper West Region of Ghana. Semi-structured questionnaires were administered to community members (N=160) to identify the various users of water, assess quality and identify adaptation measures to climate change with respect to water resources. The GPS coordinates of the water resources from which samples were collected have been integrated into ArcGIS software to enable a spatial representation of the water resources in study area.

Results from the study indicate that 100 percent of the respondents rely on boreholes, 23.1 percent rely on rivers, 3.1 percent rely on boreholes and 4.1 percent rely on constructed dams. Water quality analyses indicate that the various sources of water have varied quality. Nitrate ranged from 0.37 to 12.8 mg/L, phosphate from 0 to 1.62 mg/L, iron from below detection to 12.2 mg/L and arsenic from 0.001 - 0.5 mg/L for both the dry and wet season. The perception of water quality varies significantly among the communities. The perception of water colour (Kruskal-Wallis statistics = 29.102, p-value < 0.0001), smell (Kruskal-Wallis statistics = 27.612, p-value < 0.0001) and taste (Kruskal-Wallis statistics = 29.783, p-value < 0.0001) vary significantly among the respondents of the communities. Domestic purposes, irrigation, livestock use and construction were the main uses of water identified. The number of conflicts recorded 15

years ago exceeds the occurrence of conflicts currently. However, 18.1 percent of the respondents believe that water related conflicts will increase should the current challenges persist. The traditional instituted water management practices are highly resorted to, and managed by the WATSAN committees in each community

DEDICATION

I dedicate this thesis to my Dad, Mr. J.W. Abu (Late), my mom, Madam Alimata Abu, my siblings Abu Brenda Ariba Zarhari (PhD) and Abu Benjamin, and to my aunty Rahinatu Suleman for their support and encouraged throughout my studies; and to all the community members of the Lawra District for their contribution and time towards the completion of this thesis. Thank you.

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LIST OF ACRONYMS

AAS	Atomic Absorption Spectrophotometer
CSIR	Centre for Scientific and Industrial Research-
EC	Electrical Conductivity
EPA	Environmental Protection Agency
FES	Friedrich Ebert Stiftung
GAWU	General Agricultural Workers' union
GEOR	Ghana Environmental Outlook Report
GIDA	Ghana Irrigation Development Authority
GSS	Ghana Statistical Service
GWSA	Ghana Water and Sanitation Agency
IPCC	Intergovernmental Panel on Climate Change
IWRM	Integrated Water Resource Management
NASAC	Network of African Science Academies
NGOs	Non Governmental Organisations
NTU	Nephelometric Turbidity Unit
SPSS	Statistical Package for Social Science
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
UN	United Nations
UNICEF	United Nations International Children's Education Fund
UNEP	United Nations Environment Programme
UNJMP	United Nations Joint Monitoring Programme

WATSAN	Water and Sanitation Committee
WRI	Water Research Institute
WHO	World Health Organisation
WRC	Water Resources Commission

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

The Intergovernmental Panel for Climate Change (IPCC) projects that between 75 and 250 million people in Africa by the year 2020 could be exposed to the consequences of climate change and variability (IPCC, 2014). Increased water stress, with effects on hydro power generation, declining agricultural productivity (both crops and livestock) due to droughts and flood events, the incidence and geographic range of diseases such as malaria and cholera, reduction in fish production and infrastructure damage from flooding are some impacts expected. The IPCC states that "*Climate change will amplify existing risks and create new risks for natural and human systems. Risks are unevenly distributed and are generally greater for disadvantaged people and communities in countries at all levels of development. Risk of climate-related impacts results from the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability and exposure of human and natural systems, including their ability to adapt*" (IPCC, 2014).

Many freshwater supply sources are already over allocated, suffer degraded water quality and are often not in sufficient condition to support life. This challenge is intensified by climate change and may have the tendency to cause conflicts. Many have suggested that instead of outright civil war, climate variability is likely to heighten the risk of communal conflicts. For instance erratic rainfall, which reduces the accessibility of water and arable land, could be reasons for violent attacks against other communities to secure access to scarce resources (Fjelde & Uexkull, 2012).

The increase in temperature in some regions have reduced working hour in hot sunny days due to the heat discomfort and health related complications. Erratic rainfall pattern increases the likelihood of crop failure and decreased production yields due to unpredictable farming periods (NASAC, 2015). In semi-arid regions, the high rate of population increase coupled with recent droughts are putting a lot of pressure on water resources hence the call for new approaches in water and related conflicts management (Ragab & Prudhomme, 2002).

The good aspect of the climate change challenge is that there are technologies and instruments which when employed, will keep climate change at a manageable level (Anderson & Bows, 2008). Adaptive measures will be required to avert the negative impacts of climate change since mitigation measures will not immediately offset the challenges faced. IPCC (2007)defines adaptation as *"adjustments in natural or human systems in response to actual or expected climate change stimuli or their effects, which moderates harm or beneficial opportunities"*. High adaptive capacities decrease the rate of vulnerability of communities to climate change and variability. According to IPCC (2007) African farmers have developed various adaptation options to cope with climate variability and change. Some water adaptation measures include, the improvement of infrastructural safety, increased water storage in dams, promotion of rain water harvesting prevention of urban water loss, increasing irrigation efficiency, conservation structures on agricultural land, re mapping flood plains, integrated water shed management and water demand management (NASAC, 2015). Effective water storage contributes highly to adaptation to climate change; it augments water security and improves agricultural yield (McCartney *et al*., 2012). Climate change adaptation is continuous and a dynamic process, hence there are continuous series of adaptive responses (Pelling, 2010). Adaptation however, is not a solution to climate change, but given the significance of water resources, immediate action is needed to forestall major societal impacts (NRDC, 2010). However, the efficient implementation of water related adaptation measure should be a priority of all relevant stakeholders of the society. Helping poor countries to adapt to the inevitable impacts of climate change which will intensify as a result of already existing emissions in the atmosphere is a major key to dealing with climate change (Thornton *et al.*, 2008).

The effective implementation of adaptation and mitigation depends on policies and cooperation at all scales and can be enhanced through integrated responses that link with other societal objectives to offset exposures. Existing local mechanisms and citizen-state mechanisms for resolving conflict over environmental resources and water management have had mixed success. Formal and informal local scale institutions, such as community groups, appear to have more ability to respond and more trust than the formal institutions of the state, such as courts of law (Goulden & Few, 2011). Adaptation and mitigation responses are strengthened by common enabling factors. These include effective institutions and governance, innovation and investments in environmentally sound technologies and infrastructure, sustainable livelihoods and behavioural and lifestyle choices (IPCC, 2014).

Access to water in the context of climate change and variability will soon become a limiting factor to development, since the change in rainfall pattern affects the various uses of water including, agriculture, ecosystem services and food security (NASAC, 2015). Without improved water resources management, the progress towards poverty reduction targets sustainable development in all its economic, social and environmental dimensions will be rendered unachievable (UN Water, 2010).

1.2 Problem Statement and Justification

Climate change is manifested in Northern Ghana through higher incidence of weather extremes and disasters such as increasing temperatures, and increased rainfall variability resulting in food insecurity (Akudugu *et al*., 2012). The water sector in Ghana is one major area that is impacted by climate change and therefore water planners and managers can no longer rely only on past climatic conditions for the design of water facilities, water allocation, planning and management decisions (Kankam-Yeboah *et al.,* 2011). The potential water availability from precipitation determines the availability of both surface and underground water. Domestic water availability is already a big issue in major cities of Ghana due mainly to technical inefficiencies.

The constraints on water sources availability and accessibility has direct influence on the economy of Ghana (Kankam-Yeboah *et al.*, 2011). This is because a significant population of Ghana is engaged in agriculture and access to water is critical to their livelihoods system. The recent increased attention and promotion of agriculture water management technologies such as small reservoirs reveals that, improvements in water storage and use are necessary to meet increased demands for agriculture due to increasing population (Descheemaeker *et al.,* 2010). The total demand for potable water in Ghana was 1,967,744 m^3/day whilst the Ghana Water Company Limited (GWCL) supplies 62 percent of this need, which is 605,469.69 m^3 (MWRWH, 2007). In Ghana, the demand for water per day is 140 litres per capita per day per person. This means there is insufficiency when it comes to potable water demand and supply (Abbey, 2013). In Ghana, about 50 percent of water does not get to consumers due to leakages and other mechanical faults (Uusitalo, 2002; Yeboah, 2008)In less developed and rural areas, there are still significant numbers of people who do not have access to potable water. Lack of maintenance, inadequate supply and lack of money to pay for water are some of the challenges facing water accessibility (Abbey, 2013; UNEP, 2007).

The Upper West Region's climate regime is semi-arid and people within this region are predominantly vulnerable to climate change risk and impacts. The region experiences a single wet season mostly between May and November and experiences a mean annual rainfall of about 900- 1,300 mm (Ghana Statistical Service, 2014). An analysis based on comparison of annual rainfall data between 1950-1970 and 1971-1990 showed significant decreases in Wa, the capital town of the Upper West Region by 11.3 percent (Gyau-Boakye & Tumbulto 2000). Weather extremes such as droughts and floods continually occur vigorously leading to insecure living conditions and food shortage (FES &GAWU, 2012).

Within the semi arid region, agricultural yields are reducing because farmers depend mainly on rain fed agriculture and the recurring droughts impacts negatively on yield (Mongi *et al.*, 2010). The Upper West Region, a semi arid, experiences high erratic rainfall patterns making commencement of the farming season highly unpredictable (Blench & MacDonald, 2006). Farming is the major economic activity within the area and many livelihoods are therefore climate dependent. As a result, livestock rearing is a major copping or adaptation strategy to farmers in the semiarid region (Blench & MacDonald, 2006). Livestock rearing still requires water to develop. A survey conducted by FES & GAWU (2012) reported that farms in the Upper West Region recorded very high percentages of their crops yield and livestock lost to bad weather (FES & GAWU, 2012). This is alarming should nothing be done to address the challenge of climate variability and change.

In view of this, many communities have resorted to various sources of water for irrigation farming, livestock rearing as well as domestic use (Blench, 2006). Almost all irrigation schemes in the Upper West Region (UWR) are less advanced and mostly individually owned. The water requirement of the irrigation sites are met with small reservoirs which are easy to construct and manage. Since the year 2000, the increased demand for water has triggered the construction of more small reservoirs and wells in the Upper West Region (GIDA, 2010).

Lawra District Assembly places a high priority on provision of irrigation facilities to enhance dry season gardening (Akenten, 2012). The low agricultural yields has increased the huge reliance on dugouts, wells, rivers and streams for the purpose of irrigation and other uses during the dry season. The Black Volta is the major source of water relied on for irrigation purposes as well as source of drinking water for livestock use especially for communities along the river (Akandi, 2013). According to the Ghana Irrigation Development Authority (2010) the Lawra District has twenty-four (24) major reservoirs on which the community members rely on for dry season agriculture activities and livestock water needs as well as domestic purposes. However, most of these dry up during the dry season. Animals journeying to water points destroy vegetation, cause soil degradation and contaminate the water sources by increasing sediments and turbidity levels as well as bacteria and parasites which can pose high risks to human health. Examples of disease causing bacteria and parasites include *Campylobacter*, *Salmonella spp*, and livestock parasites. Temporary pools of water created for use favour the breeding of the human-biting, malaria-transmitting mosquito *Anopheles gambiae* (Patz *et al.*, 2005).

With a changing climate, there is the need to understand how community members can effectively respond and adapt (David *et al.,* 2007; Ishaya & Abaje, 2008; Mertz *et al.,* 2009). Using Lawra District as a case study, this research seeks to understand coping strategies with regards to water use and management in the context of climate variability and change, since water is the main channel through climate variability and change is manifested.

1.3 Research Questions

The following are the key research questions of the study:

1. Where can the different sources of water be located?
2. What is the water quality of these water sources?
3. Who are the various users of water?
4. Are there conflicts in water use during water stress situations?
5. How do people respond to water stress situations and related shared water use conflicts?
6. What are the formal and informal structures in place for water management in times of scarcity?

1.4 Objectives of the study

The overall objective of the research is to assess the nature of competing uses of water and identify sustainable ways of improving water management in the Lawra District to reduce water related conflicts.

Specific Objectives

The specific objectives are to:

1. Identify the different sources of water
2. Assess the quality of water from the various sources

3. Identify the various water users.
4. Identify the drivers of conflicts due to shared use of resources
5. Identify the various response mechanisms in water related conflicts
6. Identify water management strategies in place.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Water access and availability are emerging as critical challenges to sustainable development in the 21st century (Conca, 2008). A report from the WHO indicates that more than 75 percent of people who lack access to safe drinking water are dominantly the rural folks (WHO, 2012). The ever increasing magnitude of pressure on water resources resulting from urbanization, population growth, land use change, increased irrigation, construction of dams, pollution, climate change and other impacts related to human activities and economic growth need to be addressed urgently at both local and global levels (Kpéra *et al.,* 2012).

Water in the ecosystem is recharged through rainfall. The unpredictable rainfall pattern has increased the competing nature for water among diverse users. Those mostly affected are the poor who are already struggling to cope with climate change vulnerabilities. Properly managed water resources enhance economic and societal growth and hence improve sustainable environmental services.

The drivers of climate change together with non-climate drivers and stressors interact to amplify the vulnerability of agricultural systems eventually having adverse effects on food security (IPCC, 2014). In relation to agriculture, climate change is often seen as an exacerbating factor rather than the driving force of change (DEFRA, 2012). According to UNEP (2008), agriculture accounts for about 70percent of water across the globe however, in Africa, fresh water use in agriculture is higher making demand for food the most important driver of water use in the continent (NASAC, 2013). World Water Assessment Programme, (2009), classifies the pressure on water drivers into three categories. These include demographic drivers, which include Population dynamics (growth, gender and age distribution, migration) creating pressures on freshwater resources through increased water demands and pollution. Coupled with changes in the natural landscape there is additional pressures on local water resources and the need for more water-related services. Secondly are the economic drivers, associated with global economy and water use and international trade in goods and service through ‘virtual water’. The third driver identified is the Social driver, mainly about the manner in which individual’s perception and attitude about the environment including water resources with regards to water use and demand (World Water Assessment Programme, 2009).

2.2 Climate Variability and Water

The definition of climate change according to the IPCC is the change in climatic elements over a period of time due to natural variability or anthropogenic activities. A study conducted by Linnekamp *et al.* (2011) indicate that the majority of households perceived climate change as increasing irregularity in the rainy season, and some households link this to expected sea level rise. The sequences of changes of the climate are increasingly influential drivers of water availability which in reaction with pre-existing drivers impact negatively on water quality and availability. Impact of changes in temperature, rainfall and extreme events will induce significant changes in the various components of the hydrological cycle especially on ground water recharge (Schulze, 2012). In Africa, by 2020, 75-250 million people may be exposed to increased water stress due to climate change (IPCC, 2007). Communities in the semi-arid regions suffer from both extreme and low rainfall situations at different periods of the year due to climate change variability (Kazoka, 2013). If climate variability is tied with increased demand livelihoods will be highly affected and water-related challenges amplified (UN Water, 2010).

2.3 Access to water

Water is a basic necessity in all homes and the sources of water vary in terms of location and season. "Improved" drinking water sources as any sources that are "*by nature of its construction or through active intervention, is protected from outside contamination, in particular from contamination with fecal matter.*" (UNICEF, 2014) The amount of time spent to fetch drinking water is an important measure in determining the ease or difficulty in gaining access to drinking water. Households are considered to have basic drinking water access when they use water from an improved source with a total collection time of 5-30 minutes which is approximately 100-1000m in distance for a round trip, including queuing (WHO/UNICIEF, 2012). Furthermore, the minimum required amount of water for basic needs varies between 20 and 50 litres per person per day (lpd) (Abrams, 2001; Anokye & Gupta, 2012) However in Ghana, according to the CWSA (2007), the minimum requirement of water for rural areas is 20 lpd. The goal of the Government through the Community Water and Sanitation Agency (CWSA) is to attain national water coverage of eighty-five (85) percent by 2015 (CWSA, 2014). Access to improved water source for urban populations in most countries in Africa is greater than 50 percent, however, in rural population, access is much lower and is extremely dire, for example in Somalia where it is less than 10 percent (NASAC, 2013). Affordability of water is a critical issue when water use and management is of concern. Most rural areas or small towns operate the pay-as-you fetch method of payment (Rossiter *et al.*, 2010). Other rural areas also operate the monthly payment or contribution system where necessary.

Majority of the population in the Lawra District are situated in the rural areas (Ghana Statistical Service, 2014). Within the study area, the people heavily rely on boreholes and other natural sources of water like rivers which dry up in the dry season (Ghana

Statistical Service, 2014). In view of this, numerous governments in West Africa have been widely engaged in the construction of dams for the purposes of agro-pastorals to address the challenges of low water storage capacity and regulate the quantities available for use (Kpéra *et al.,* 2014). The increase or decrease on the demand of water for use depends on the activities being undertaken at that point in time. Many small reservoirs constructed within these semi-arid regional have brought some diversification and generate a lot of income in some regions and others failed woefully (Nelson *et al*., 2010).

2.4 Water Quality

The fast rate of the population coupled with the rapid urbanisation and industrialisation resulting in an increase in individual and collective needs have made water increasingly scarce and often of low or reduced quality (MWRWH, 2007). Access to safe drinking water is highly import to human health and the proper functioning of the ecosystem (MWRWH, 2007; WHO, 2004). Use of water below acceptable water quality limits increase the risk of transmission of pathogens associated with poor hygiene practices, leading to food-borne and water-borne diseases, which are major health problems in impoverished communities (Patz et al., 2005). Therefore, safe drinking-water is necessary for all usual domestic purposes such as drinking, food preparation and personal hygiene (WHO, 2011).

2.4.1 Physicochemical properties of water

The levels of physicochemical parameters like pH, temperature, turbidity, conductivity and total dissolved solids have been analysed which are interact to determine the quality of water.

pH

The power of hydrogen is an important parameter that influences the quality of drinking water, as it is positively correlated with temperature and affects the solubility of metals in water. The range of pH is between 0 and 14, with seven considered as a neutral value, less than seven acidic and greater than seven basic or alkaline. The Ghana Standards Board recommends a range of 6.5 - 8.5 for drinking water (Ghana Standard Authority, 2013). However WHO recommends a range of 6.5 to 8.5. Increasing water temperature from 25°C showed no major change in pH, until the temperatures rise to 60°C. The pH of water is also positively correlated with electrical conductivity (Gupta & Saharanb, 2009) and determines the corrosive nature of water (Patil *et al.*, 2012; Rossiter *et al.*, 2010). The lower the pH, metals and other substances will be corroded or dissolved. The level of pH of a water sample affects the quality of the water for use. High pH causes a bitter taste (Omuku *et al.*, 2012), and water pipes and water-using appliances become covered with deposits. The effectiveness of chlorine is affected and there is the need for larger quantities of it in water treatment when pH low (Matilainen *et al*., 2010).

Temperature

Temperature affects the physical, biological and chemical properties of water, and determines the rate at which chemical reactions occur in water. However, WHO has no guidelines for drinking water temperature (WHO, 2004). Temperature is positively correlated with conductivity and total hardness of water (Patil *et al.*, 2012). The ability of water to transport or deposit suspended materials depends on temperature. Temperature of water affects the irrigation practices as well as livestock production through excessive evaporation and increase heat stress respectively (Marshall *et al.*, 2015).

Turbidity

Turbidity is an expression of the optical property of water that causes light to be scattered and absorbed rather than transmitted in straight lines through water. It is measure in Nephelometric Turbidity Units (NTU) (Postolache *et al.*, 2007). For good drinking water, turbidity must always be low, preferably below 1 NTU, however WHO recommended guideline for turbidity is 5 NTU (WHO, 2004). Materials that cause water to be turbid include clay, silt, finely divided inorganic and organic matter, algae, soluble coloured organic compounds, and plankton and other microscopic organisms (Wang *et al*., 2010). According to WHO (2004), high levels of turbidity can protect microorganisms from the effects of disinfection, stimulates the growth of bacteria and exert a significant chloride demand. Turbidity affects the colour of water and makes it less likely to appeal to consumers especially when it is greater than 4 NTU (Hansen, 2014). Anthropogenic activities, especially farming along the banks can lead to the high levels of sediments in surface water through runoffs and rain storms (Fianko *et al*., 2007). Higher turbidity levels in drinking water cause gastrointestinal diseases. Aquatic lives also suffer insufficient light in the water when the turbidity is high affecting the food change in that ecosystem.

Total Dissolved Solids

Total Dissolved Solids (TDS) is the combined measure of all organic and inorganic substances in liquids in molecular ionized suspended form (Kumar & Desai, 2011). A high concentration of TDS is an indicator of possibly high volume contamination and further investigation may be recommended (Abdulai, 2014). Water with extremely low concentrations of TDS may also be unacceptable to consumers because of its flat, insipid taste; it is also often corrosive to water-supply systems (Sarikhani *et al*., 2015).

Conductivity

Conductivity is the ability of water to conduct electrical current. This depends on the ionic strength of the water body. Conductivity increases as the concentration of ions increase, since electrical conductivity is generated by ions in solution. The determination of electrical conductivity provides a rapid and convenient way of estimating the concentrations of dissolved ions or the amount of total dissolved salts. Conductivity is also a good measure of salinity in water such as chlorides from salts. Conductivity is also affected by temperature: the warmer the water, the higher the conductivity.

2.5 Heavy Metals and their Health Implications

Access to safe drinking water is very critical to the health of humans especially in poor countries through consumption of unsafe food and water. About 4 billion incidents of diarrhoea occur annually, leading to 2.2 million deaths (WHO/UNICEF, 2000).

2.5.1 Arsenic

Arsenic is a naturally occurring element is dominantly found in areas where arsenic rich ores are found within the soils and sediments (Polya & Charlet, 2009). When found in water, it is usually in the form arsenates or arsenates. Exposure to arsenic is very hazardous, especially when bioaccumulation is taking place and has the tendency to cause inflammations and respiratory disorders to organisms (LaValle, 2009). Infants however, are the most vulnerable when exposed to arsenic because they have the tendency of developing cancer and other skin problems (Kapaj *et al.,* 2006). According to Gavrilescu (2005), in soluble forms, arsenic moves with water and attaches itself to surfaces of solids or sediments since is not soluble but can change its form depending on the environmental characteristics.

2.5.2 Iron

Iron is one of most abundant free state occurring element in the entire earth crust. Iron is an active metal and forms bounds with halogens (Abdulai, 2014). Two conditions must be met to enable the absorption of iron onto a surface, first, the iron must be separated from its organic complex and secondly, the ferric iron should be reduced to ferrous iron. . Excessive iron brings about the growth of tumours, lung, liver, stomach and kidney cancer (Torti & Torti, 2013).

2.6 Nutrients

2.6.1 Nitrate

Nitrate (NO_3^-) is a water-soluble and is made up of nitrogen and oxygen (Vitòria *et al*.,2004). Nitrates are found in several different forms in terrestrial and aquatic ecosystems. Nitrate is the more stable oxidized form of combined nitrogen in most environmental media (USEPA, 2006). Nitrates occur naturally in mineral deposits, in soils, seawater, freshwater systems, the atmosphere, and in biota. Groundwater levels of nitrates may range up to 20 µg/l or more, with higher levels occurring in shallow aquifers beneath areas of extensive development (USEPA, 2006). Nitrates are essential plant nutrients, but in excess amounts they can cause significant water quality problems (Tilman *et al*., 2002). Together with phosphorus, nitrates in excess amounts can accelerate eutrophication, causing dramatic increases in aquatic plant growth and changes in the types of plants and animals that live in the stream (Tilman *et al.*, 2002). This, in turn, affects dissolved oxygen, temperature, and other indicators.

2.6.2 Phosphate

There are many sources of phosphorus, both natural and human. The sources could also be classified as point source or non-point source. Some none point sources of pollution include runoffs from wastewater treatment plants, runoff from fertilized lawns and cropland, failing septic systems, runoff from animal manure storage areas, disturbed land areas, drained wetlands, water treatment, and commercial cleaning preparations (Cordell *et al.*, 2009). Higher concentrations of phosphates cause health threats to animals and humans.

2.7 Classification of water use

Globally, water use is classified into three categories namely agricultural use, domestic use and industrial use, where 70 percent of water is used for Agriculture, 20 percent for industrial use and the remaining 10 percent for domestic use (Barker, 2009). Similarly in Ghana, according to the Water Resources Commission, the major consumptive uses in Ghana are water supply, irrigation and livestock watering. Domestic and industrial urban water supplies are based almost entirely on surface water, either impounded behind small dams or diverted by weirs in rivers. In other countries such as Northern Benin, constructed dams are used for multiple purposes such as drinking water for livestock and human beings, fishing, vegetable growing, swimming, bathing, washing, road and house construction, food cropping, and cotton farming (Kpiera *et al.*, 2012). However, the influence of climate change on water quality and availability threatens the sustainability of water use and amplifies the risk of lacking water for social and ecological systems (Engles & Lemos, 2010).

Water and water scarcity are now global concerns, not only from the economic and ecological points of view, but also from that of ethics: to provide continued access to water for the poor and vulnerable as competition over the resource increases (Vincent, 2003). Pressure on water resources and ecosystems, resulting from urbanization, population growth, land use change, increased irrigation, construction of dams, pollution, climate change and other impacts related to human activities and economic growth need to be addressed urgently at both local and global level (Kpiera *et al*., 2012).

2.7.1 Domestic use

WHO defines domestic water as being *'water used for all usual domestic purposes including consumption, bathing and food preparation'*(WHO, 2002). Domestic water supply is very important since most of the water use activities occur at home (Howard *et al*., 2003). Domestic water use can be put into three classifications: (i) Consumption (drinking and cooking), (ii)Hygiene (including basic needs for personal and domestic cleanliness), and (iiii) Amenity use (for instance car washing, lawn watering) (Howard *et al*., 2003). In addition, (Thompson *et al*., 2001) suggest a fourth category, Productive use, which of higher relevance to the poor in developing countries. Productive uses of water include animal watering, brewing and construction.

2.7.2 Irrigation

In Africa much of agricultural production is currently rain fed making climate variability a key control on food security (NASAC, 2015). Farming is the dominant occupation in the Lawra District. Since the rainfall pattern is normally uni-modal, all the farmers cultivate their farms within the stipulated rainfall period. The higher temperatures and decreasing precipitation rates experienced in low income countries, especially where adaptive capacity is low, depresses crops yields (Tazeze *et al*., 2012). Increased temperature results in increased plant stress, leading to increased crop water needs (Lobell *et al*., 2008). The situation stated above has increased the reliance on irrigation. This has increased the reliance on irrigation, which, is one of the most valuable rural development investment that impacts positively on food security and poverty eradication in semi-arid tropical countries (Nedumaran & Thomas, 2009).

Since the 1990s, the prospects of vegetable production prompted the instigation of several alternative irrigation methodologies which are continually evolving. Across the African continent, irrigation as an adaptation practice in agriculture has positively influenced the yields of many farmers to meet food demand in their localities. However, improper management of irrigation leads to excessive water scarcity, water pollution and ecosystem degradation (Ndamani & Watanabe, 2015). Most irrigation systems have experienced various forms of failures and their designers do not consider the practical operation of systems installed. Appropriate designs are therefore currently required to address the increasing competition for water (Vincent, 2003).

2.7.3 Livestock use

Rearing of livestock is regarded as a supplementary activity to crop farming (Poku, 2009). However, climate change affects livestock directly by affecting their health, well-being and rate of production as a result of the increased ambient temperature and concurrent changes in heat exchanges between the animal and it environment and subsequent decrease in fees intake (Jingar *et al*., 2014; Singh *et al*., 2012). However, institutional and policy changes, capacity building for livestock keepers, effective alternative breeding strategies and science and technology development are some adaptation strategies livestock owners can implore to achieve maximum productivity (Calvosa *et al*., 2010; Taqi *et al*.,2013).

2.7.4 Use in small industry activities

Small industry activities are businesses which mostly individually owned, employ a few people and rarely have high volumes of sales. In rural areas in the northern part of

Ghana, for example, women are mostly involved in brewing of 'pito' (a local beer made from millet or sorghum) or shea butter production as a means to support their financial situations (Quaye, 2008). In northern Namibia, brewing is a common economic activity for rural people especially and requires high quantities of water (Sturm *et al*., 2009). Both small scale industrial activities are done all year round by women in the study area.

2.8 Water demand

The definition of water demand is the amount of water required by the consumer as compared to water demand which is defined as water required by the supplier (Abbey, 2013; Lamptey, 2010). Globally, fresh water scarcity is on the ascendency and this can be attributed to the increasing demand by a steadily growing population (Gyamfi, 2012). Precipitation variability and higher temperatures would also lead to the water demand for irrigation purposes (Algamal, 2011). On the basis of surface water, the consumptive demand by the year 2020 is projected to be about five (5) billion m^3 which is equivalent to 12 percent of the total surface water resource in the country. As at 2004, the urban water supply coverage is estimated at 55 percent, the rural and small town coverage is 51.6 percent, whilst irrigation water demand has been projected by 2020 to be about 400,000 m^3, to cover a projected area of 100,000 hectares (MWRWH, 2007). According to the CWSA, per capita water consumption is at 20 lcd (CWSA, 2010).

2.9 Water related conflict

The heavily polluted diminishing water is causing the increasing population to demand more water (Gyamfi, 2012) and this can be seen as a potential sources of conflicts within those areas (Carius *et al*., 2004) The poorest groups in society are heavily affected due to their incapacity to adapt hence face a greater risk of violence as competition for increasingly limited resources increase (Reed *et al.,* 2013).

According to Kpéra *et al*. (2012), herders interviewed during a research in Nikki, Benin reported that the main impediments to the use of dams for both irrigation and pastorals are the recurrent conflict between irrigation farmers and herders, water pollution, and the silting up of the dams and the farmers were blamed for impeding access to the dams as well as the council of Nikki for taking a position favourable to the farmers. In terms of conflict potential, climate threats to livelihoods are much more consequential in the context of rapid economic development of other sectors or groups within the economy, especially when explicitly favoured by national policies (USAID, 2014). The potential solutions to water are mostly local in nature involving the members of various communities themselves (Dodman & Mitlin, 2013).

2.10 Water pollution and related issues

Water for immediate consumption through food should be of very high standards posing no significant health risk to human health (Howard & Bartram, 2003). Water related health risk manifest through poor hygiene. These include diarrhoeal and other diseases transmitted through the faecal-oral route; skin and eye diseases, in particular trachoma and diseases related to infestations, for instance louse and tick-borne typhus (Howard & Bartram, 2003). A significant population of the northern part of Ghana suffer unmet needs for safe drinking water hence the need for "improved" but also "safe" water management and water treatment options in Northern Ghana (Cheng *et al*., 2013). In developing countries, the quantity of water supplied is mostly focused on or prioritised as compared quality (Barrow, 2005).

2.11 Public perception of water quality

Perceived poor water quality, may create potential health risks through the use of unsafe alternative sources of water (Essien, 2014). A study carried out in British Colombia, Canada showed that taste, smell, colour and particulate matter, were rated as the most important water quality indicators to respondents. Cotruvo *et al*. (2014) agree that is difficult for a consumer to discern water quality changes apart from aesthetic factors like taste, color and turbidity. Hoko (2008)in his study in Bindura, Zimbawe reported that is a higher satisfaction for taste as compared to soap consumption, meaning that generally hard waters may still be acceptable for drinking purposes. There was no strong relationship between taste and conductivity, and also between taste and iron.

2.12 Water management strategies

The rapid rate at which greenhouse gases are released through anthropogenic activities are challenges for many water planners because it affects water resources variability and availability for use (Mango, 2010). The challenge with the increasing completion for water should involve the scientific development of ecological framework and effective plans (Vincent, 2003). In Ghana, water management strategies are handled by various institutions. Currently, the Ministry of Water Resources, Works and Housing is responsible for the management of water in the country at the higher level. The development of the Community Water and Sanitation Agency (CWSA) as well as the Ghana Urban water supply to manage the operations of the Ghana water supply company limited which is mandated to establish, operate and control water and sewerage facilities in the country. The CWSA has a duty to facilitate the provision of safe drinking water and related sanitation services to rural communities and small towns in the country (CWSA, 2012). Woodhill (2008) described institutions as formal and informal rules that enable and structure all forms of social interaction and create stability and order in society. Institutions may include different forms of organization, regular patterns of behaviour, language, laws, customs, beliefs, and values. Many sub- regions have developed legal and regulatory reforms mechanisms however, active implementation, monitoring and controls are often lacking. (Johnson *et al*.,2016) the integration of the customary law and models of water governance can be implemented to deal with water issues so as the make the system more efficient and effective. Water development and management should be based on a participatory approach, involving users, planners and policy makers at all levels.

Policies for dealing with the environmental challenges especially in relation to water and climate change should not be perceived as a barrier for economic development but the reverse (Ross *et al*., 2016). At local levels, the formal rules are not naturally respected and decentralization does not mean that local people are enabled to manage their environment; since water sources are constantly polluted by the various activities. A further distinction can be made between informal rules set by the town council, and informal rules that are part of local cultures (Kpiera *et al*., 2012). Informal rules, set by the town council include anyone who wants to use water for house construction should pay 2000 FCFA (D 3.05) per house; transhumant herders are to pay 50 FCFA (D0.076) per animal before the animals are allowed to enter the area around a dam; access to the dams from the dyke by humans and livestock is banned; movement corridors are delimited and livestock should remain within the corridors when accessing the dams; opening of farms within 1000 m from the edge of a dam is forbidden; vegetable farming is authorized only downstream of the dams; it is forbidden to wash and swim in the dams and washing is allowed only downstream of the dams (Kpiera *et al.*, 2012).

CHAPTER 3

MATERIALS AND METHODS

3.1 Study area

The Lawra District (latitude 10^0 25'N and $11^0$00"N and longitude $2^0$25'W and $2^0$45'W) is located in the north-western corner of Ghana, in the Upper West Region. It shares boundaries with the Nandom District to the north, Lambussie- Karni District to the east, to the southern and western parts with the Republic of Burkina Faso.

The District covers about 1,051.2 square km, which represents about 5.7percent of the Region's total land area. The District has 157 communities with 95percent of the inhabitants settling outside the District capital, Lawra. The population density is about 89 per square kilometer, making it the most densely populated district in the region. There is a high employment rate of 26,269 (78 percent) out of population of 34,269 above 15 years. The unemployed constitute only 2percent while 7,189 (20 percent) are inactive people within the active age cohort (Ghana Statistical Service, 2014). Majority of the employed (96 percent) are involved in agriculture and small scale business. Farming is the major occupation of most of the settlers of this area. Major crops cultivated include sorghum, groundnut, maize, soya bean and cowpea. The presence of the Black Volta and various interventions by the Assembly in collaboration with some NGO's has broadened the scope of irrigation farming within the District. Also, animal production is a key agricultural activity undertaken by the people to supplement incomes from crop farming especially in the dry season. However yield from this occupation mostly is low hence most able bodied men and women migrate to the urban areas or to the southern part of Ghana to seek alternative sources of income.

3.1.1 Population

The total population of the District according to the 2010 Population and Housing Census is 54,889 people a growth rate of 1.9 percent .It comprised of 26,346 (48 percent) males and 28,543 (52 percent) females, indicating a sex ratio of 1:1.08. The Districts takes a share of 7.8 percent of the population of the Upper West Region (Ghana Statistical Service, 2014). With a growth rate of 1.9, however, the population of the District was estimated at 58,127 in 2013, with a male population of 29,005 and a female population of 30,226. The District has a youthful population, about 51 percent of the people are within 15-64 age cohorts, 41 percent are children of less than 15 years, whiles the remaining 8 percent are the aged of above 64 years (Ghana Statistical Service, 2014).

3.1.2 Water supply, sanitation and health

There is a variety of water sources within the district and the nature of the use determines the type of water resource used. The main source of drinking water for the urban dwellers is pipe-borne (inside and outside dwelling and public tap) accounting for seven out of every ten households (71.8 percent) compared to less than two percent for their rural counterparts. Thus, in rural areas the main source of drinking water is bore-hole, pump or tube well (74.5 percent) as well as for other domestic uses (71.1 percent) as compared to 22.5 percent for urban households. The use of water from rivers or streams as main source of water for other domestic uses is more prevalent in the rural areas (4.9 percent) than in urban areas (0.1 percent). This however could be attributed to non-availability of these sources in most part of a year (Ghana Statistical Service, 2014).

Solid waste is mostly dumped into public dumps or open space or dumped indiscriminately and open burning. Two main forms of liquid waste disposal are mostly throwing the liquid on the open compound or onto the streets. It is observed that 63.2 percent of the households in the district do not have toilet facilities and therefore openly defecate in bushes, or open spaces/fields, or use public toilet (17.0 percent). Only 33 households constituting 0.4 percent use bucket or pan as toilet facility. Pit latrine usage is prevalent in rural (12.4 percent) than urban areas (7.7 percent) (Ghana Statistical Service, 2014).

3.2 Physical features of the district

3.2.1 Agro-ecological features

The District lies within the Guinea Savannah Zone which is characterized by short grasses and few woody plants. Common trees in the District consist of drought and fire resistant trees such as *Adansonia digitata, Parkia bigloboa, Vitellaria paradoxa* and *Acacia nilotica*. Livestock production is a very dominant activity in the District because of the vast grassland and because it contributes significantly to household incomes. The prolonged dry season causes the grass to dry up and the subsequent bush burning leaves the area patchy and mostly bare of vegetation. Prolonged dry seasons also affect the vegetative cover, transpiration and subsequently average annual rainfall totals, affecting rain-fed agriculture and resulting in low agricultural yields. Consequently, the torrential early rains cause soil erosion due to the bareness of the land, affecting the soil structure and profile.

The climate of the District is the tropical continental type with the mean annual temperature ranging between 27°C to 36°C. The period between the months February and April are the hottest in the District. During April and October, the Tropical Maritime air mass which gives some forms of rain. The erratic rainfall pattern coupled with declining agricultural yield causes the migration of the youth, a factor associated with the underdevelopment of the human resource base of the District (Ghana

Statistical Service, 2014). Fig 3-1 is the mean yearly rainfall pattern from the year 1982 to 2014. The highest rainfall was recorded in the year 1999 whilst the least was recorded in 1990.

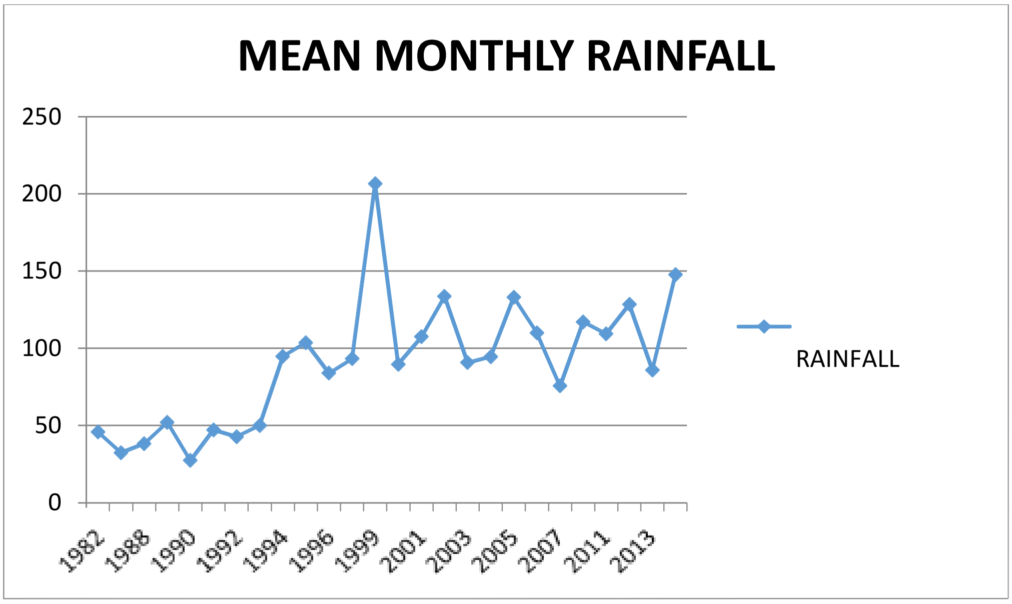

Figure 3.1 Mean monthly rainfall

3.2.2 Geology and Soils

The Geology of the Lawra District is mostly Birimian rocks with scattered outgrowth of granite. The Birimian rock is the made of metamorphic, sedimentary and plutonic rocks. Some preliminary explorations surveys within the District show that, there is the presence of minor occurrences of manganese, traces of gold, diamond, iron ore and clay. However, the well- developed fracture pattern in the rocks, the potential for obtaining ground water in the District is very high.

The combination of the birimian and granite rocks develops the laterite soil of the area. There are also strips of alluvial soils along the flood plains of the Black Volta as well as sandy loams along some of its tributaries. The nature of the soil together with other traditional land use practices are key influencers of the persistent short fall in food production (Ghana Statistical Service, 2014)

3.2.3 Drainage

The Black Volta River forms a boundary to the west with the Republic of Burkina Faso. It is the major river in the area. The Black Volta River has several tributaries which run through the communities in the district. Some major tributaries within the District are Kamba/Dangbang, Nawer and Duodaa. These water bodies are mostly used for irrigation purposes especially during the dry season.

3.2.4 Topography

The topography of the Lawra District is generally a gently slope with a small number of hills ranging between 180 and 300 metres above sea level.

3.3 Reconnaissance visit

A reconnaissance visit to the Lawra District was conducted in August, 2015 to observe and study the suitability of the environment for the research. Most of the sampling sites and communities were selected within this period taking into consideration the type of water sources present. Secondly, the survey was conducted to familiarise the researcher with the community members and inform them of the intended study; key persons who assisted with the survey were also identified.

3.4 Sampling

3.4.1 Sampling sites

3.4.2 Water sampling

Water sampling was carried out during two different periods of the survey. The first sampling was done in November, 2015 and the second in March, 2016, both of which fell within the dry season period. Various water sources sampled include boreholes, rivers and a dam, which were all identified during focus group discussions in the various communities. In all, 19 samples were taken in the first exercise and 16 in the second exercise

3.4.2.1 Treatment of sample containers and sampling procedures

Strict measures were adhered in avoiding contamination of samples during sampling; handling and storage, working conditions were carefully selected. At each sampling site, a water sample was collected into a plastic bucket for *in-situ* measurements after the bucket has been initially rinsed with the sample. Temperature, Conductivity, Total Dissolved Solids and pH were measured on site using a HORIBA U-51 series multi-meter water quality checker.

A two-litre polyethylene sampling container was filled with water at each site. The sampling containers with well-fitted stoppers were pre-treated by washing with distilled acetone to get rid of organic substances such as grease and fat residues. They were then washed with detergent and rinsed with de-ionized water and then soaked in 1.0 M nitric acid solution for 48 hours. The containers ware finally rinsed several times with de-ionized water before used for taking and holding the water samples. Water samples that were not analyzed immediately were stored in a refrigerator below 4 °C. Precautions were taken as to the number of days the samples could be stored to avoid inaccuracy. Samples for the heavy metals and nutrients analyses were kept in separate bottles and transported to laboratory in an ice chest to maintain low temperatures. Two drops of nitric acid were added to the heavy metals samples to preserve the metals ions in the water.

3.5 Laboratory analysis of water samples

Samples were brought to room temperature (25 °C) before analyses were carried out. Nitrogen-Nitrate and Phosphate-Phosphorus were determined using the HACH Direct Reading spectrophotometer (2010 model) whilst Atomic Absorption Spectrometer model Perkin Elmer PinAAcle 900T was used for heavy metal analysis (Iron and Arsenic). Phosphate and nitrate were analysed in the water samples because of the agricultural activities in the study area. Iron and arsenic were analysed due to the geological nature of the study area.

3.5.1 Nitrogen Nitrate (NO_3^- -N) analysis

The method used for the Nitrate analysis was the Cadmium Reduction Method. The nitrate level in each sample was measured using Nitrate Powder Pillows in a direct reading Hach spectrophotometer Model DR. 2010. Ten (10) ml of the sample was measured into sample cell of the Spectrophotometer. One Nitraver 5 Nitrate Reagent Powder Pillow was added to the sample. The mixture was then shaken vigorously for 1 minute. Five minutes was allowed for the solution react. An orange colour of the mixture indicates the presence of Nitrate. After five minutes, another cell was filled with 10ml of only the sample (blank). The blank sample was placed in the spectrophotometer for calibration. Then the prepared sample was placed into the cell holder to determine the Nitrate concentration at 500nm in mg/l (HACH, 1996).

3.5.2 Phosphate (PO_4^{3-}) analysis

A 10ml of water sample (the prepared sample) was placed in the sample cell. Phos Ver 3 Phosphate Powder pillow was added to the cell content and swirled immediately to mix. A two-minute reaction period was allowed. A blue colouration of the mixture indicates the presence of phosphate. Another sample cell (the blank) was filled with 10ml of sample and placed into the cell holder to calibrate it. After reaction period the prepared sample was placed into the cell holder and the level of phosphorus was determined at 890 nm. The Spectrophotometer displayed the results in mg/l PO_4^{3-} (HACH, 1996).

3.5.3 Turbidity

The level of turbidity, influenced by presence of suspended matter, such as clay, silt, finely divided organic and inorganic matter, plankton and other microscopic organisms, is dependent on size, shape and refractive properties of the particles. Turbidity of the water was determined using Turbidimeter Model 2100P (Hach). Twenty five (25) millilitres of sample was measured and placed into the cell holder. The amount of turbidity was directly determined using Turbidimeter Model 2100P. Each measurement was preceded by a calibration.

3.5.4 Iron, Total (Fe^{3+}) analysis and Arsenic (As)

Atomic Absorption Spectrometry method for heavy metals was used to determine the level of iron and arsenic in the samples. In flame atomic absorption spectrometry, a sample is aspirated into a flame and atomized. A light beam is directed through the flame, into a monochromator, and onto a detector that measures the amount of light absorbed by the atomized element in the flame. For some metals, atomic absorption exhibits superior sensitivity over flame emission. Because each metal has its own characteristic absorption wavelength, a source lamp composed of that element is used; this makes the method relatively free from spectral or radiation interferences. The amount of energy at the characteristic wavelength absorbed in the flame is proportional to the concentration of iron and arsenic in the sample over a limited concentration range. Most atomic absorption instruments also are equipped for operation in an emission mode (Huai *et al*., 2003).

3.6 Mapping of GPS points

A Duno SD Trimble was used to take GPS point of the sampling site of the various water sources. These points were then analysed using the ARC GIS software to produce a map with the location of the various water sources.

3.7 Interviews and questionnaire survey

Four communities in the Lawra District were purposively selected after a reconnaissance survey of the District was conducted. They are Kampuoh, Methaw, Tolibri and Oribili. The communities were primarily chosen based on the different sources of water sources availability. Secondly, the willingness of the community members was also a basis for the selection of these communities. Focus Group Discussions and questionnaire administration were the key modes of information acquisition from the respondents. These were chosen based on the objectives of the research being conducted. The question in both the questionnaire and focus group guide were directed at achieving the aims of the research.

Initially, eight focus group discussions were organised mostly with a maximum number of 15 females or males groups. In each community two separate focus group discussions were conducted for males and females. This was to solicit their views on water source, water use water related conflicts and water management. After the questionnaire administration, two separate focus group discussions were organised to validate information derived from the survey in each community for men and women. Within each District, the households were conveniently randomly selected. Household members who were present in their households were interviewed using through sessions questionnaire administration. These sessions were conducted to have an in-depth view of their individual concerns on water use, water related conflicts and water management within the District. In addition, some key informants were interviewed on water management.

3.8 Data analysis

Descriptive statistics were used to summarize the socio-demographic patterns of the respondents and water quality parameters. To test for statistically significant differences among communities and water sources for the various water parameters, an analysis of variance (ANOVA) or the non-parametric Kruskal-Wallis test was performed where appropriate. ANOVA was used when the normality assumptions were met and Kruskal-Wallis test when these assumptions were not met. In the case of significant difference, Student-Newman-Keuls's post-hoc test (following ANOVA) or pairwise Wilcoxon test (following Kruskal-Wallis test) was done for pairwise mean comparisons. Similarly, to test if there is a difference between seasons, a t-test (when assumptions were met) or a two-sample Wilcoxon test (when assumptions were not met) was used when appropriate. Shapiro-Wilk's test was conducted for normality and Levene's test for equality of error variances to test the normality and the homoscedasticity assumptions, respectively.

The Kruskal-Wallis test was performed to better understand how respondents' perception of water quality (of the main water source in all the communities, which is borehole) varies among the communities. For this analysis, indicators of water quality as perceived by the respondents (namely colour, smell and taste) were used A simple logistic regression tested if the likelihood or probability that a respondent reported a water related conflict in the past 15 years and in the present (each considered as a dependent variable) is affected by its gender, number of water sources (available or accessible for a household), distance to the main water source (as measured by time spent to get to the main water source), and time spent in the community in search of water.

All statistical analyses were performed using SPSS version 20.0 and R software version 3.2.5.

CHAPTER FOUR

RESULTS

4.1 Demography

The study conducted involved community members of both sexes who were randomly selected. The total number respondents were 160, of which 56 percent were females and 44 percent males (Figure 4-1).

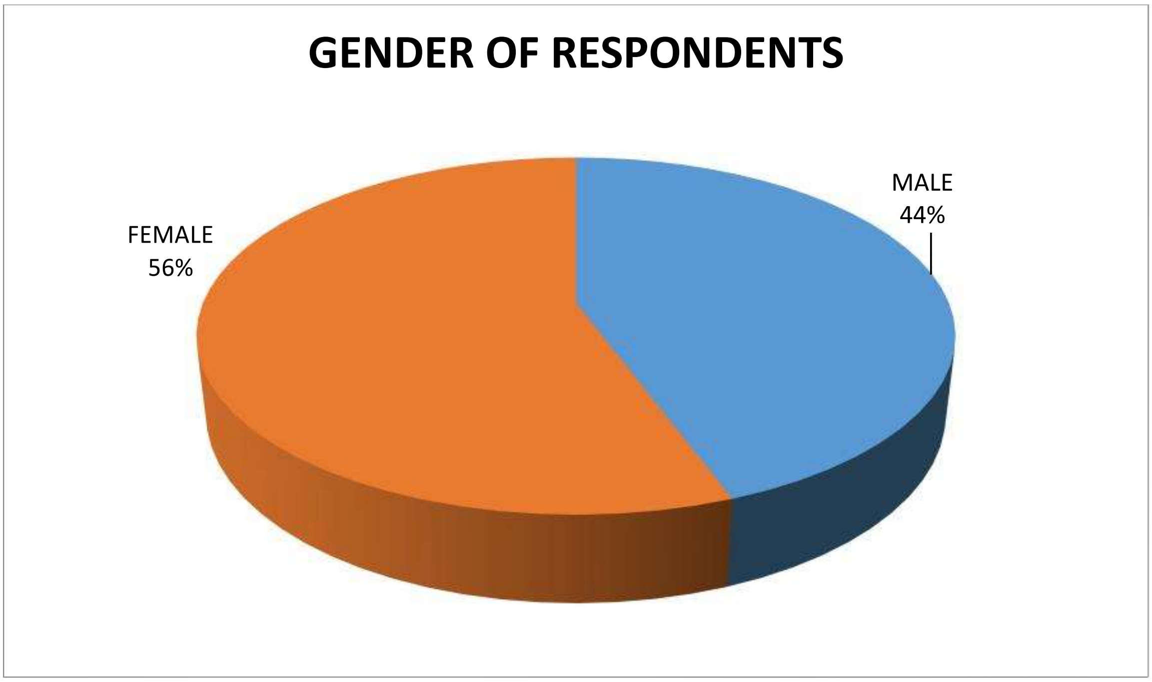

Figure 4.1 Gender of Respondents

The age group with the highest number of respondents was 30-39 years (31.4 percent), whilst the least number of respondents was above 60 years (7.5 percent). The respondents within the age groups of 20-29 and 40-49 years recorded the same proportion of the total (21.3 percent), whilst the remaining 10percent were between the ages 50-59. In terms of marital status, married respondents were the majority (94 percent), whilst the singles were the least in number at just one (1) percent of the total (Figure 4-2).

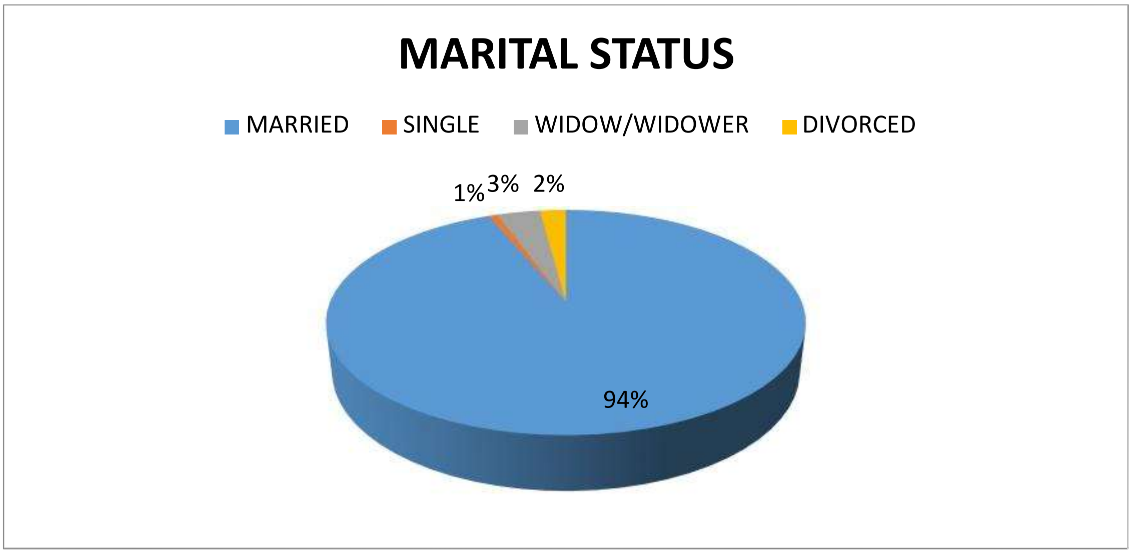

Figure 4.2 Marital Status

The level of education of respondents interviewed is generally low (Figure 4-3). More than half of the number of the respondents (70 percent) has no form of formal education. Only 1 percent of the respondents have tertiary education, which is the least recorded. The percentage of respondents who have been to primary school is 16 percent and to secondary school, 13 percent.

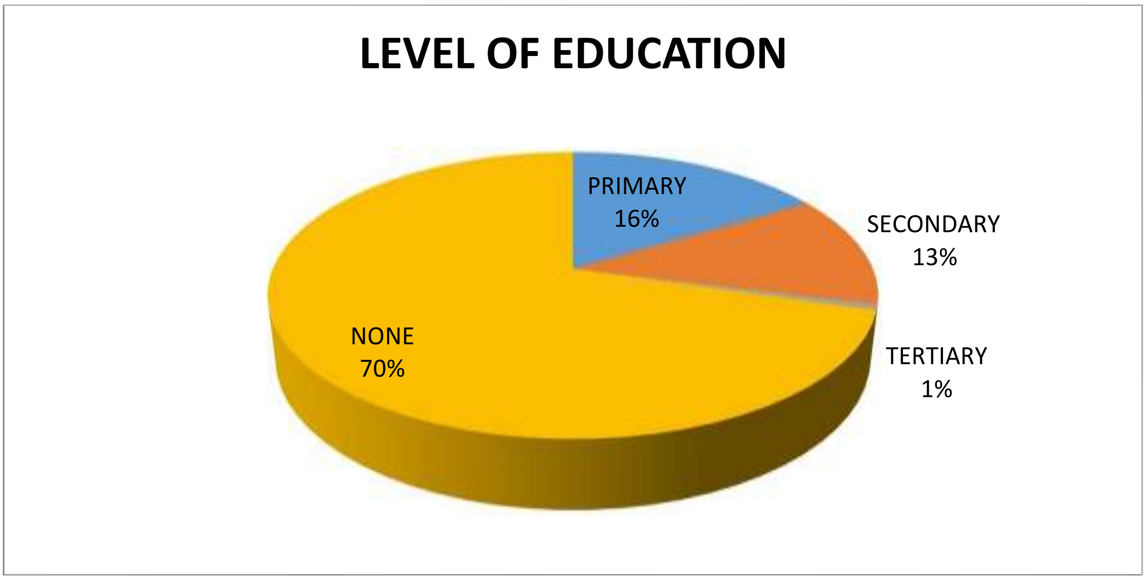

Figure 4.3 Level of Education of Respondents

From the survey, more than half of the respondents (59 percent) are farmers. Traders constitute 11 percent of the respondents, whilst 23 percent are both farmers and traders. Six percent of the respondents are engaged in other occupations like carpentry, hairdressing, fashion designing and mechanics. A number of respondents (11.3 percent) have more than occupation. Figure 4-4 shows the occupational distribution of the respondents.

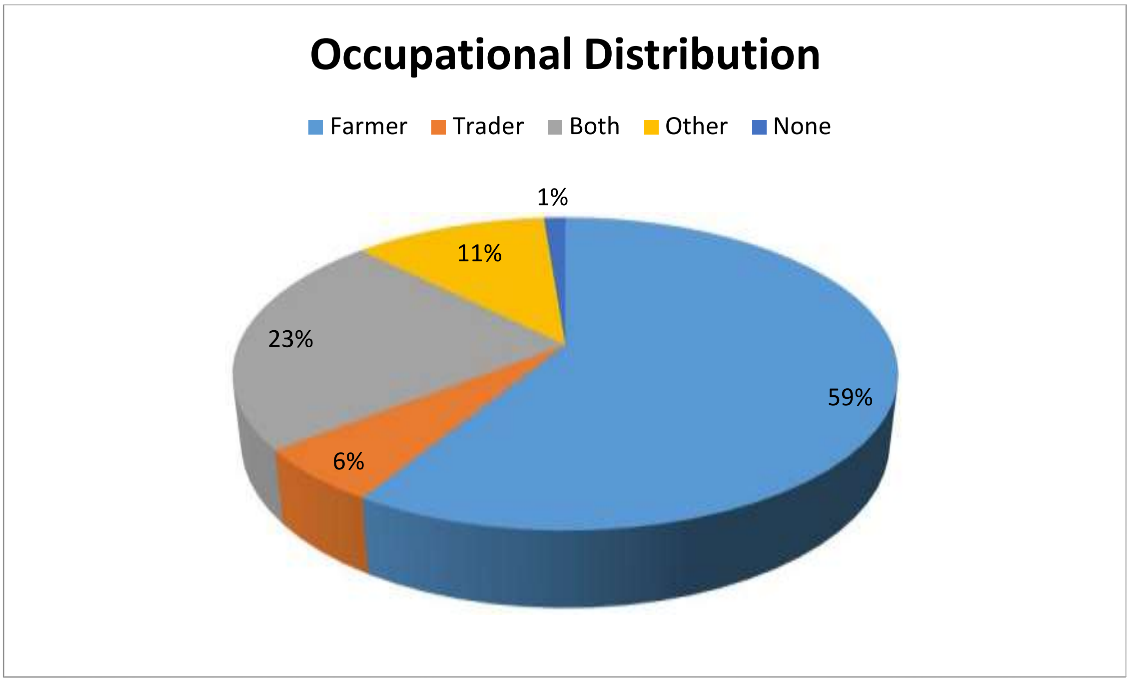

Figure 4.4 Occupational Distribution of Respondents

Of the total respondents interviewed, 35.6 percent were heads of households, whilst the remaining 64.4 percent were members of the household. From the survey, 40.6 percent of the respondents indicated that there was no household member that had travelled out of the community or migrated to other areas. The remaining respondents, (59.4 percent) confirmed that members of their households had migrated to other parts of the country.

4.2 Water sources identified

4.2.1 Types of sources

The first objective of the research is to identify the major different sources of water in the study area. Figure 4-4 shows the different sources of water identified by the respondents and the percentage of respondents who rely on the various sources for water.

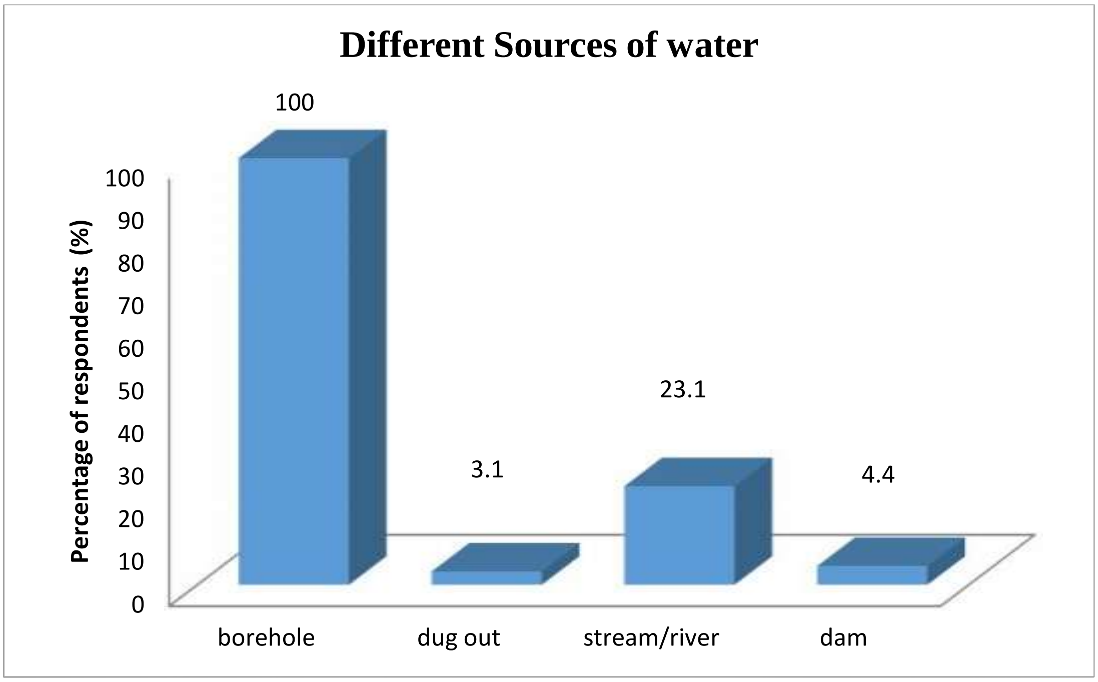

Figure 4.5 Different sources of water

The major sources of water in the communities are boreholes, which is the primary source of water for all respondents, dugouts, streams/rivers and dams. A majority of respondents (72.5 percent) rely on one source for household use, 24.4 percent of the respondents rely on two different sources and 3.1 percent of rely on three sources.

4.2.2 Number of sources of water

The number of sources of water for each community varied among the communities surveyed, from one (1) to five (5) (Table 4-1). Kampuoh community have one source, which is a borehole. Oribili community has three sources, which include two boreholes and the Black Volta River. Tolibri community has four boreholes, whilst

Methaw has five sources of water, including three boreholes, one dam and the Black Volta River.

Table 4.1 Number of water sources per community

Community	Number of water sources			
	Borehole	Dam	River	Total
Kampuoh	1	-	-	1
Oribili	2	-	1	3
Tolibri	4	-	-	4
Methaw	3	1	1	5

4.2.3 Location of sources and travel time

The GPS locations of the water sources sampled in the various study communities were mapped Figure (4-5). In total, there were thirteen (13) various water sampling sites (shown as green dots on the map) from four (4) communities surveyed.

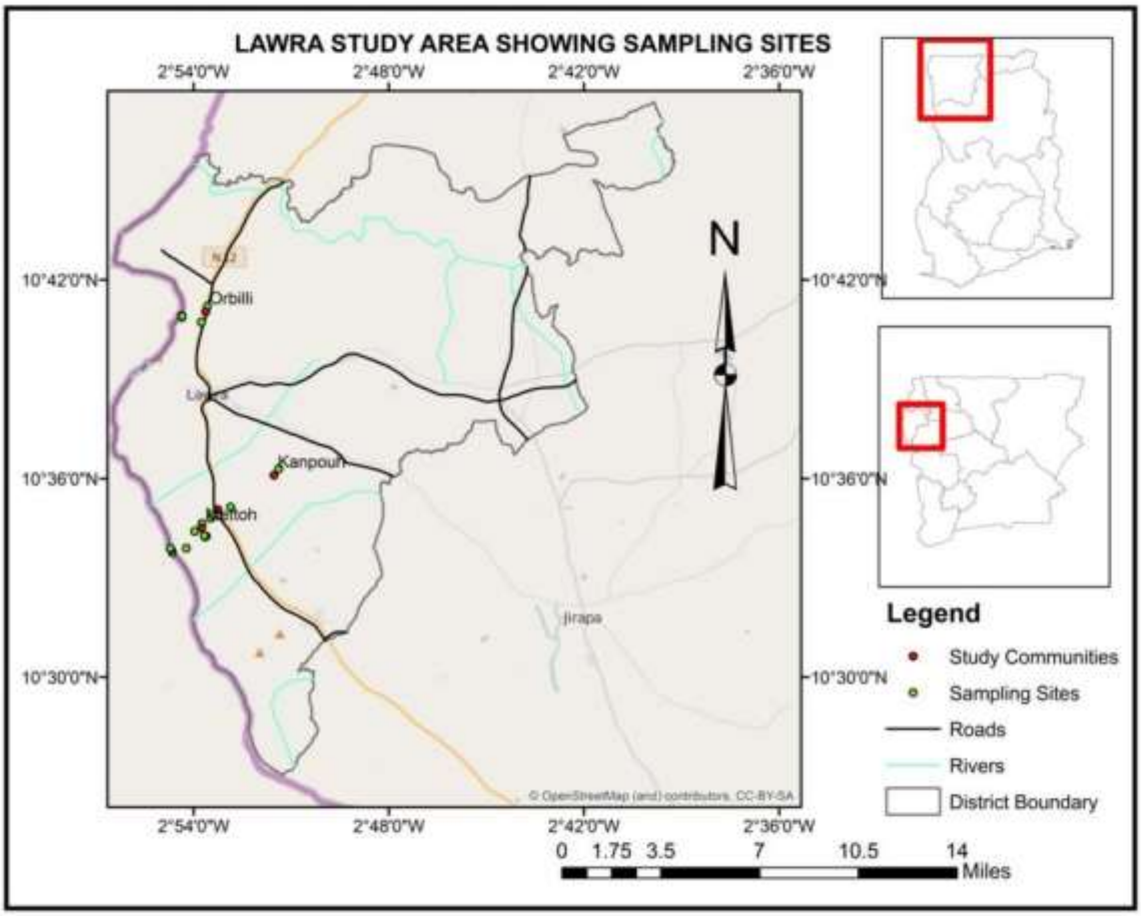

Figure 4.6 Map of sampling site

Boreholes are the primary source of water for all respondents and the duration in travelling time from home to the primary source of water and back is generally less than one hour (Table 4-2). 50 percent of the respondents take between 30 to 60 minutes from their homes to the water source and back, whilst 46 percent take less than 30 minutes.

Table 4.2 Duration in fetching water from the Boreholes.

Time	Number of respondents	Percentage (percent)
< 30	73	46
30-60	80	50
< 60	7	4

4.3. Physical parameters of water samples

The quality of the water sampled during the rainy season and the dry season in the various communities was determined. Parameters assessed are pH, Electric Conductivity (EC), Total Dissolved Solids (TDS), turbidity, temperature, phosphate, nitrate, iron and arsenic. The means of physical parameters assessed in the Dry Season (DS) and Wet Season (WS) for the samples from Boreholes (Be), Rivers (Rr) and Dam (Dm) are described below.

4.3.1. pH of water

The pH values in the wet season ranged between 5.67 and 6.55 whereas the dry season ranged from 5.10 to 7.05 (Figure 4-7). With the exception of the dam in Methaw, all the water samples obtained during the dry season had higher pH values than the wet season samples. The dam in Methaw also recorded the lowest pH value (5.1) in the dry season. The highest pH value (7.0) was recorded in Methaw as well from the Black Volta river samples taken in the dry season. Figure 4-7 illustrates the pH of all the water samples for the two seasons.

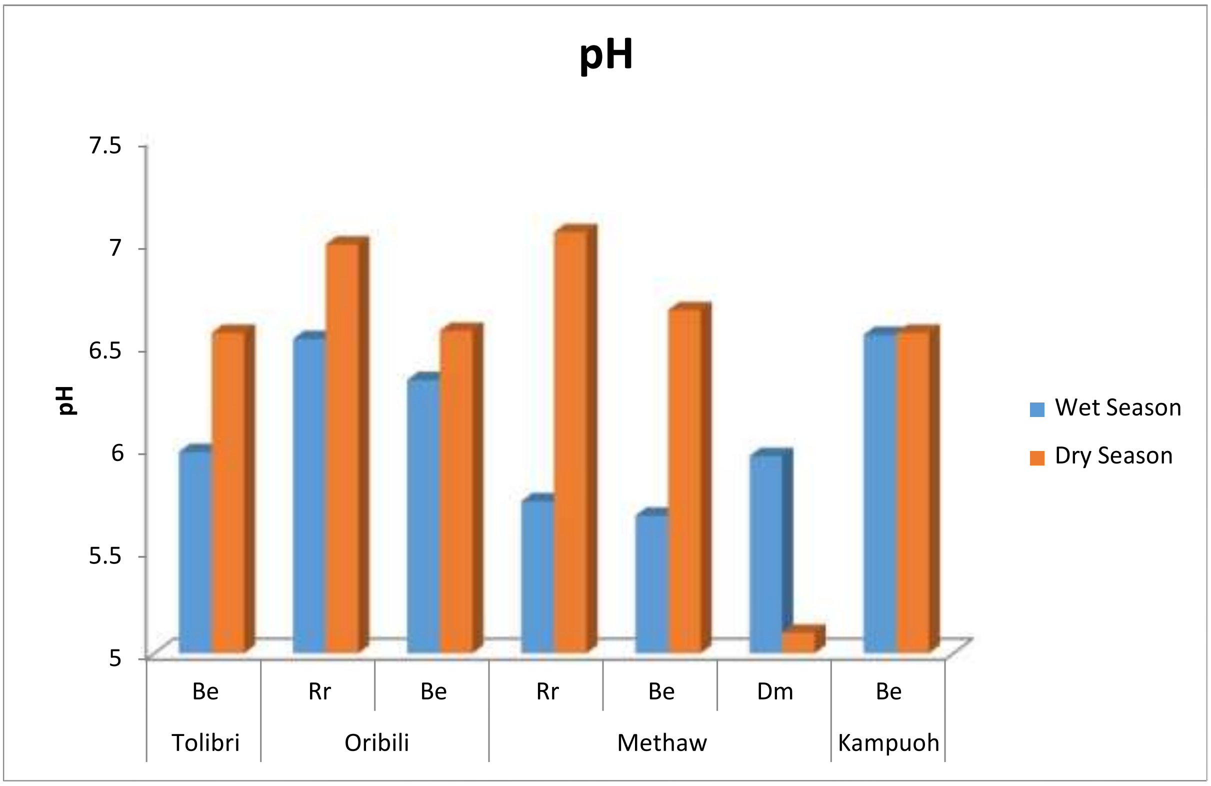

Figure 4.7 pH values (Be - Borehole; Rr - River; Dm - Dam)

There is no statistically significant difference among the water sources for pH. The Mean pH for river (6.58±0.58) is higher than borehole (6.26±0.44) and dam (6.01±0.37) (Table 4.3).

Table 4.3 Mean and Standard Error (SE) of water sources.

Water source	Mean pH (±SE)
Borehole	6.26±0.11
Dam	6.01 ± 0.15
River	6.58±0.17

4.3.2 Electrical Conductivity (EC)

The EC values of water samples in the wet season ranged from 20 µS/cm at Methaw to 250 µS/cm at Oribili (Figure 4-8). In the dry season, values ranged from 75 µS/cm to 252 µS/cm at Methaw and Oribili, respectively. Across the survey communities, except for Tolibri, electrical conductivity of water samples in the dry season was higher than the wet season. The boreholes recorded higher electrical conductivity as compared to the rivers and dam. There is no significant variation in the electrical conductivity of water sources of the different community ($p = 0.577$). In other words, the mean values of electrical conductivity of water sources of the four (4) communities are similar, not statistically different.

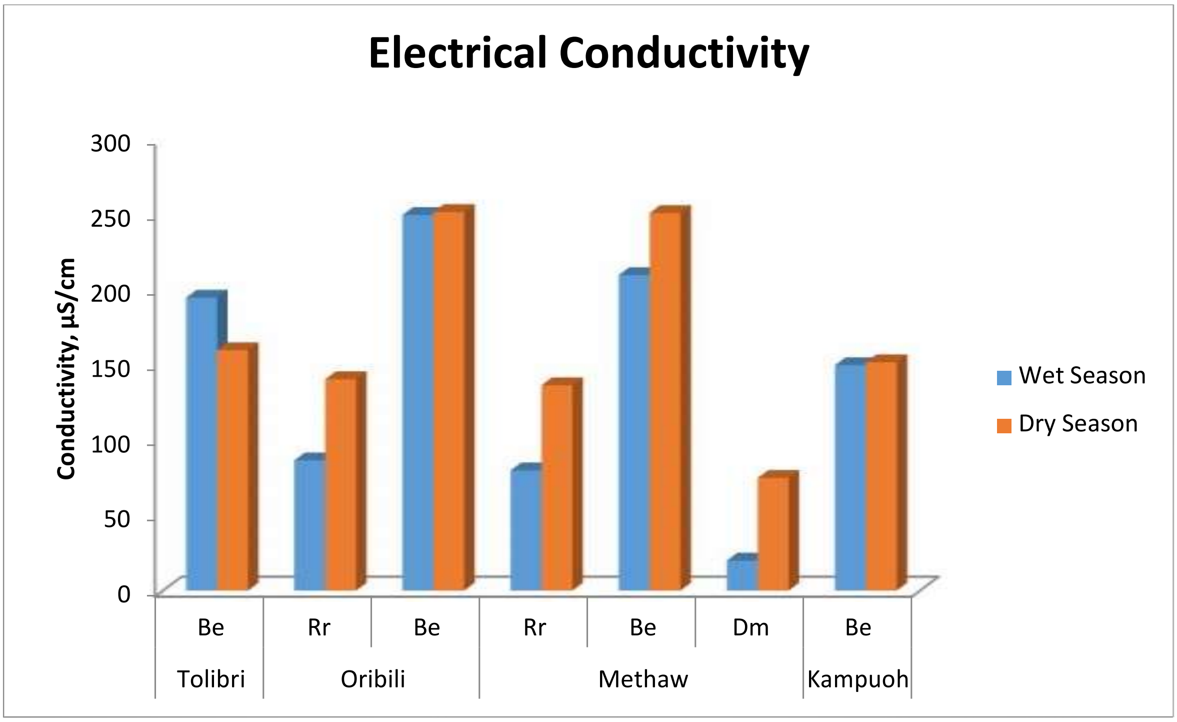

Figure 4.8 Electrical Conductivity values (Be - Borehole; Rr - River; Dm - Dam)

4.3.3 Total Dissolved Solids

The TDS values of water samples collected in the wet season ranged from 35 mg/L to 125 mg/L in Methaw (Figure 4-9). In the dry season, values ranged from 10 mg/L at

Methaw to 140 mg/L at Oribili. The boreholes recorded higher total dissolved solids in both seasons as compared to the rivers and dam. The lowest value recorded for both seasons (35 mg/L in dry and 10mg/L in wet) was for the dam in Methaw.

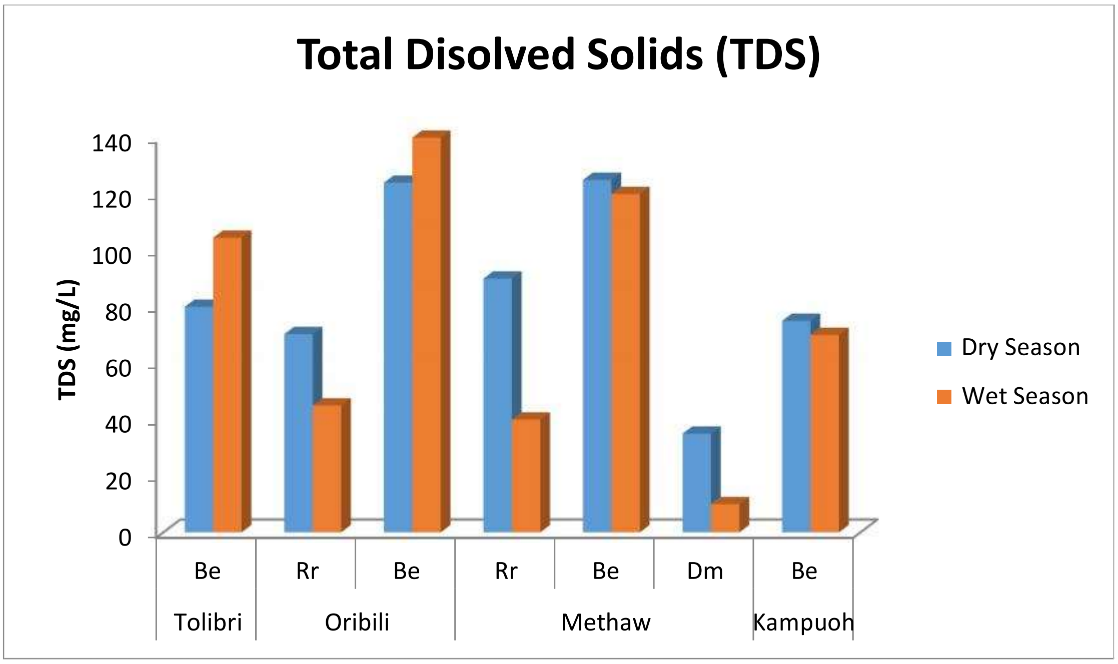

Figure 4.9 Total Dissolved Solids values (Be - Borehole; Rr - River; Dm - Dam)

There is a statistically significant difference among the water sources for TDS (Kruskal-Wallis statistics = 20.851, df = 2, p-value < 0.001). Mean TDS for borehole (109.82±8.27) is higher than river (61.33±8.12) and dam (29.17±10.52) (Table 4.4).

Table 4.4 Mean TDS and Standard Errors (SE) for water sources

Water source	TDS (±SE)
Borehole	109.82±8.27^{a}
Dam	29.17±10.52^{b}
River	61.33±8.12^{b}

4.3.4 Turbidity

Turbidity of the water samples obtained in the wet season ranged from 0.3 NTU in the boreholes to 165.33 NTU in the dam at Methaw, whereas the dry season values ranged from 0.3 NTU in the boreholes at Kampuoh to 12125 NTU at the Methaw dam. The boreholes generally recorded very low turbidity values across the seasons. Figure 4-10 illustrates the mean TDS values.

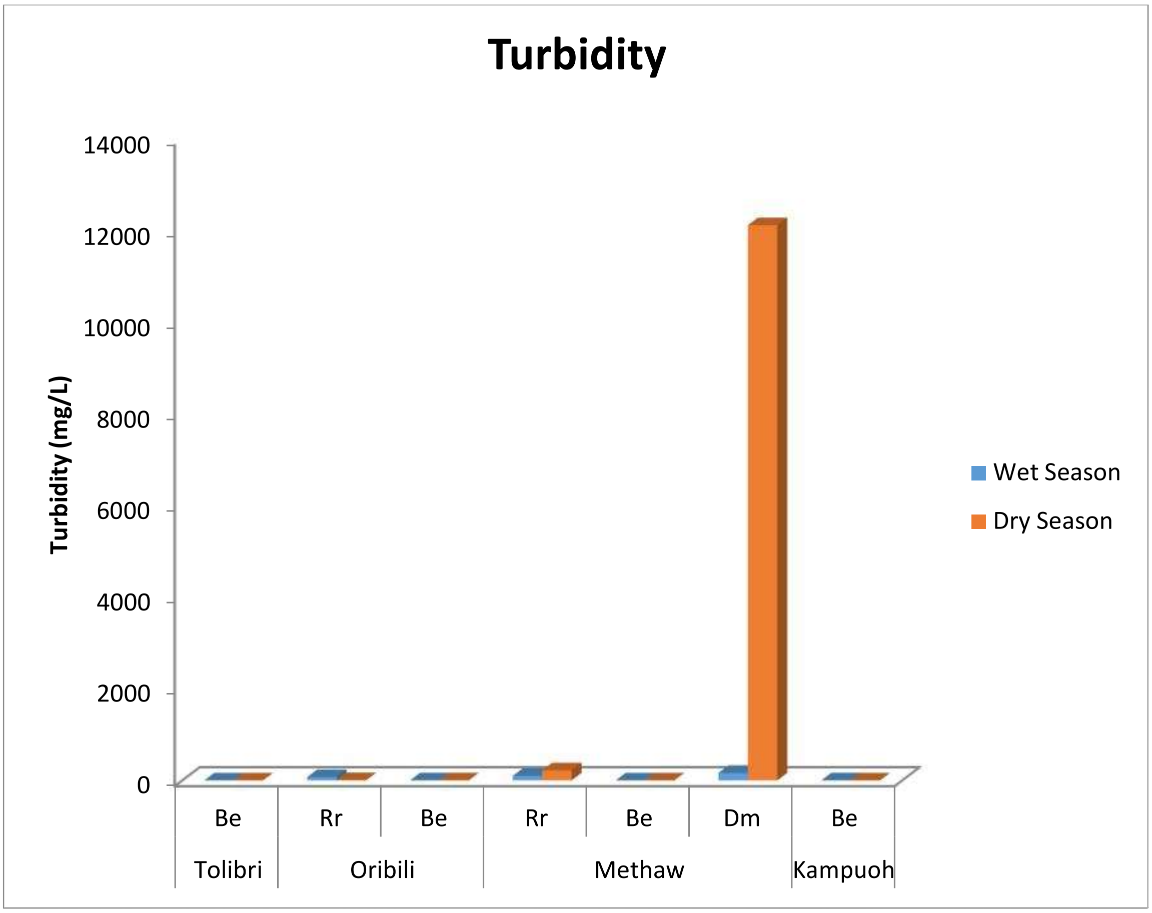

Figure 4.10 Turbidity values (Be - Borehole; Rr - River; Dm - Dam)

There is a statistically significant difference among the water sources for Turbidity (Kruskal-Wallis statistics = 21.14 df = 2, p-value < 0.001). Mean turbidity for borehole (0.87±0.48) is the least value as compared to the means of the river (120.39 ±64.6) and dam (4124.4 ±6779.51) (Table 4.5).

Table 4.5 Mean Turbidity and Standard Error for various water sources.

Water source	Turbidity (±SE)
Borehole	0.87±0.12
Dam	4124.4 ±2767.72
River	120.39±18.65

4.3.5 Temperature

The temperature of water samples recorded in the wet season ranged from 22.7 °C at Oribili and Tolibri to 31.63 °C in Methaw. In the dry season, water temperature recorded ranged from 24 °C at Oribili to 32 °C at Kampuoh. On average, water samples from the dry season recorded higher temperatures as compared to the wet season (Figure 4-11).

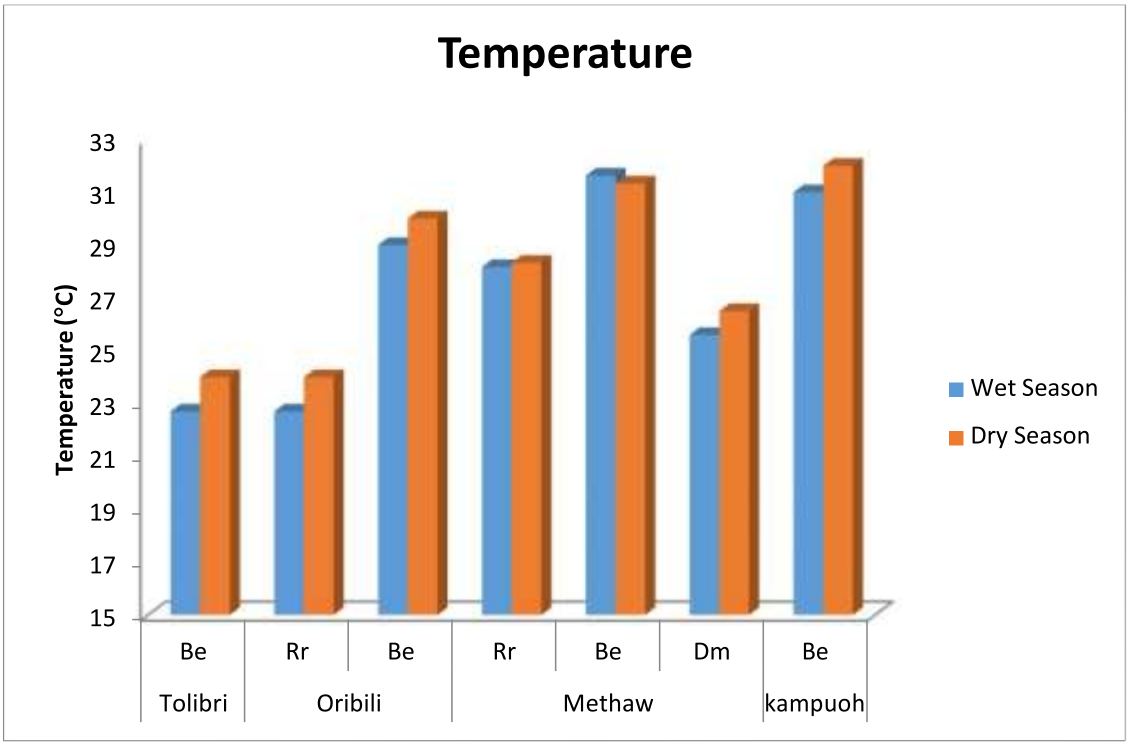

Figure 4.11 Temperature Values (Be - Borehole; Rr - River; Dm - Dam)

4.4 Nutrients and Heavy Metals

The mean values of phosphate, nitrate, iron and arsenic in water samples obtained in the dry and wet season are described below.

4.4.1 Phosphates

The concentration of phosphate in water samples obtained during the wet season ranged from 0 to 1.62 mg/L, and in the dry season from 0.24 to 1.62 mg/L (Figure 4-12). The minimum (0 mg/L) and maximum (1.62 mg/L) values of phosphate in the wet season were recorded at Kampuoh and Methaw, respectively, both from boreholes. For the dry season, the river in Oribili recorded the least phosphate value (0.24 mg/L), and the community's borehole the highest (0.98 mg/L).

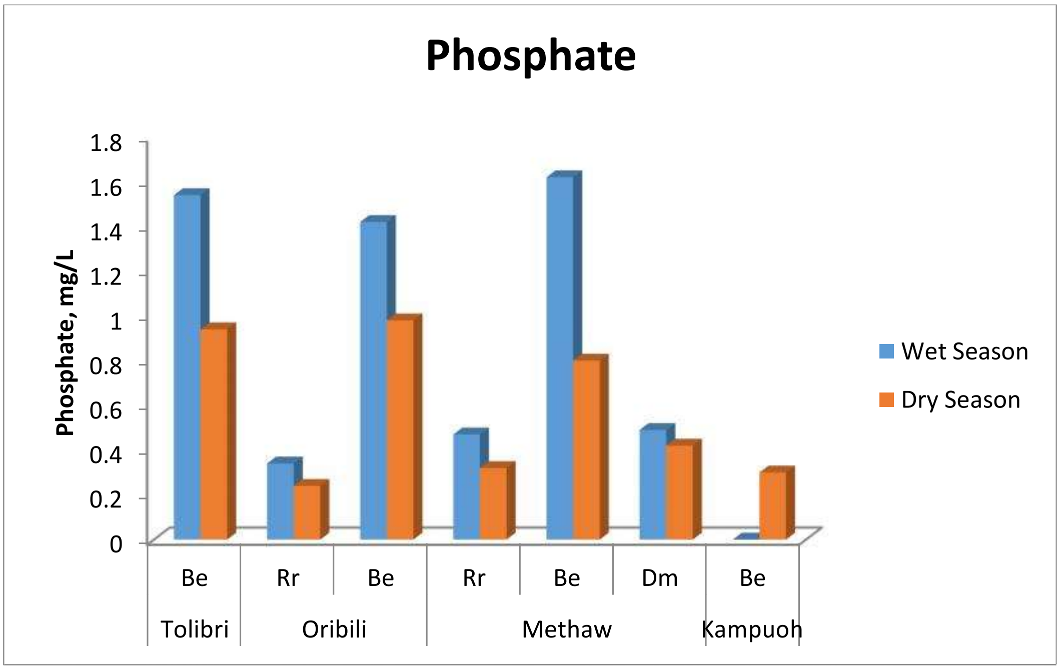

Figure 4.12 Phosphate Values (Be - Borehole; Rr - River; Dm - Dam)

There is a statistically significant difference among the water sources for Phosphate (Kruskal-Wallis statistics = 21.78, df = 2, p-value < 0.001). Mean Phosphate for borehole (1.28±0.52) is higher than river (0.34±0.15) and dam (0.44±0.23) (Table 4.6).

Table 4.6 Mean Phosphate and Standard Error for various sources of water

Water source	Phosphate (±SE)
Borehole	1.28±0.13
Dam	0.44±0.09
River	0.34±0.04

4.4.2 Nitrates

The concentration of nitrates in water samples analysed in the wet season ranged from 0.37 mg/L to 1.7 mg/L (Figure 4-13). Also, the values of nitrates in the dry season ranged from 0.42 mg/L to 12.8 mg/L. In the dry season, the river at Methaw recorded the highest level of nitrate at 12.8 mg/L.

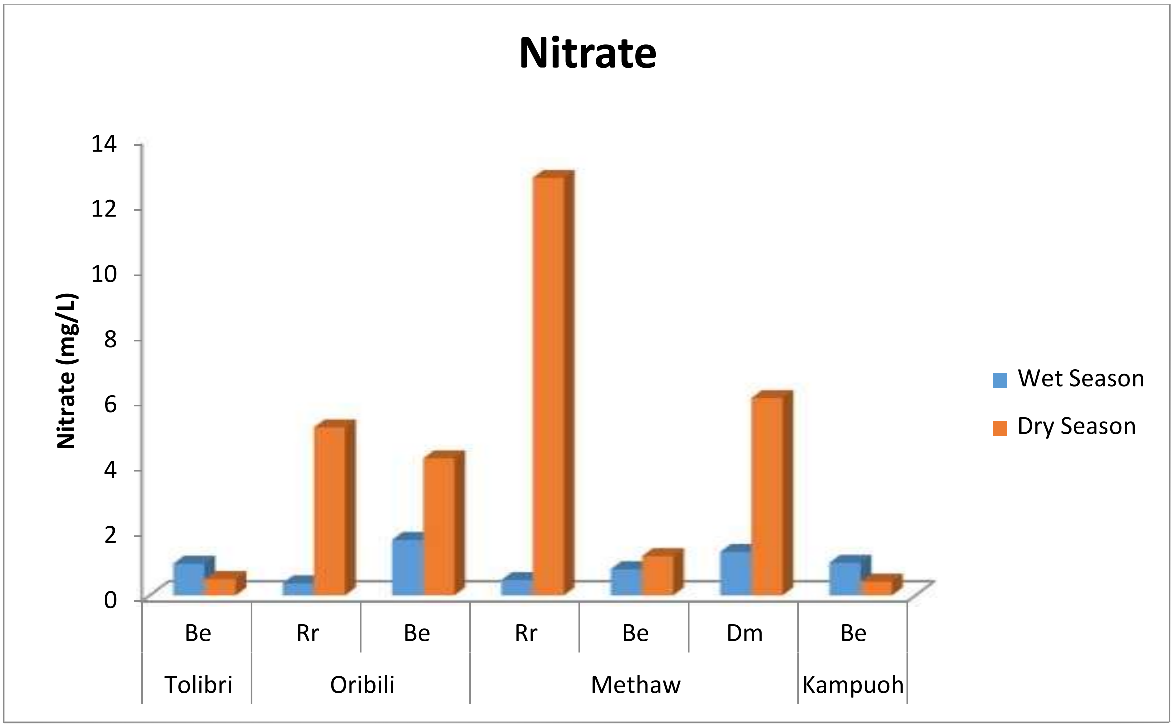

Figure 4.13 nitrate Values (Be - Borehole; Rr - River; Dm - Dam)

There is no statistically significant difference among the water sources for nitrate (Kruskal-Wallis statistics = 4.76 df = 2, p-value > 0.001). Mean nitrate for borehole (0.89±0.96) is higher than river (4.62±5.31) and dam (2.73±2.62) (Table 4.7).

Table 4.7 Mean Nitrate Value and Standard Error for water sources

Water source	Mean Nitrate (±SE)
Borehole	0.89±0.23
Dam	2.73±1.07
River	4.62±1.53

4.4.3 Iron

The concentration of iron in water samples analysed in the wet season ranged from below detection limit at Kampuoh and Tolibri to 0.31 mg/L at Methaw. In the dry season, concentration of iron ranged from 0.0002 mg/L at Kampuoh to 12.20 mg/L at Methaw (Figure 4-14).

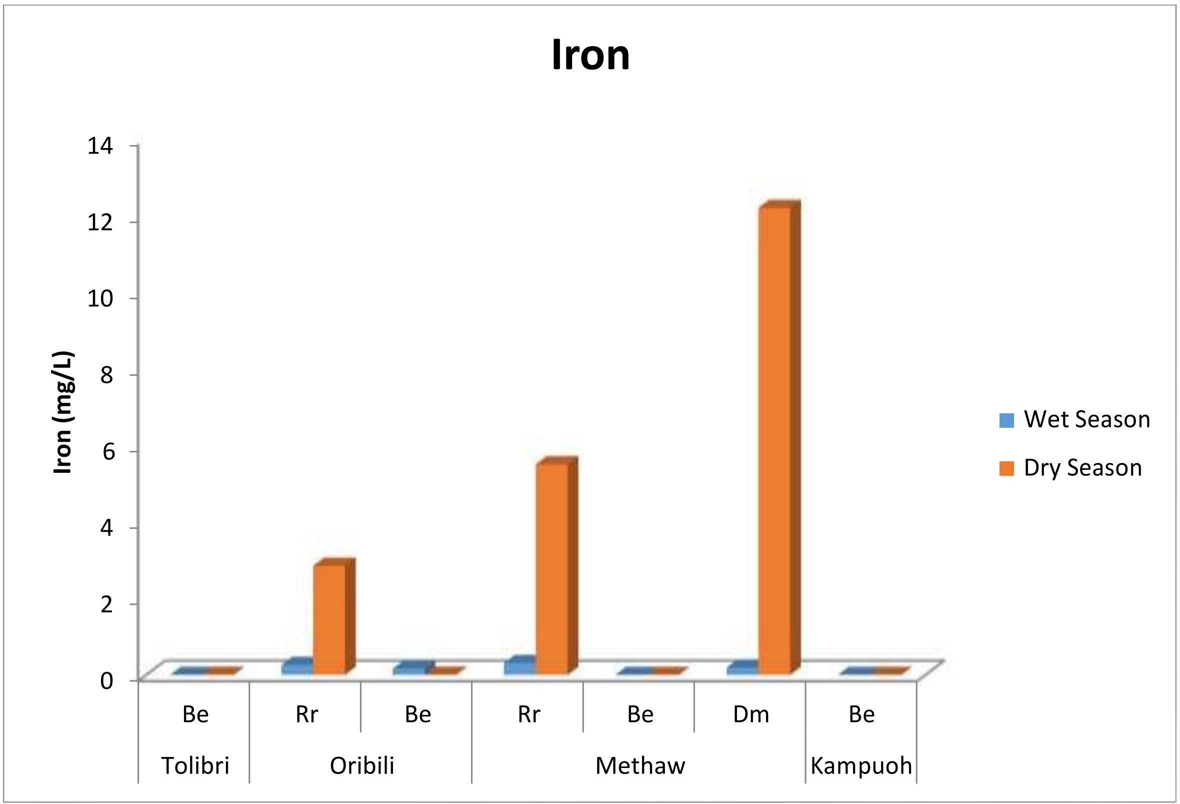

Figure 4.14 Iron Values (Be - Borehole; Rr - River; Dm - Dam)

There is a statistically significant difference among the water sources for Iron (Kruskal-Wallis statistics = 12.48 df = 2, p-value < 0.05). Mean iron for borehole (0 ±0.01) is the least mean value recorded as compared to the river (2.23 ±2.55) and dam (4.16 ±6.23) (Table 4.8).

Table 4.8 Mean Iron and Standard Error for Iron

Water source	Mean Iron (±SE)
Borehole	0±0
Dam	2.23 ±2.54
River	2.23±0.74

4.4.4 Arsenic

The concentration of arsenic in the wet season ranged from 0.0080 mg/L at Tolibrii to 0.5000 mg/L from the Oribili River (Figure 4-15). In the dry season, values ranged from 0.0001 mg/L at Oribili and Kampuoh to 0.0720 mg/L at Tolibri.

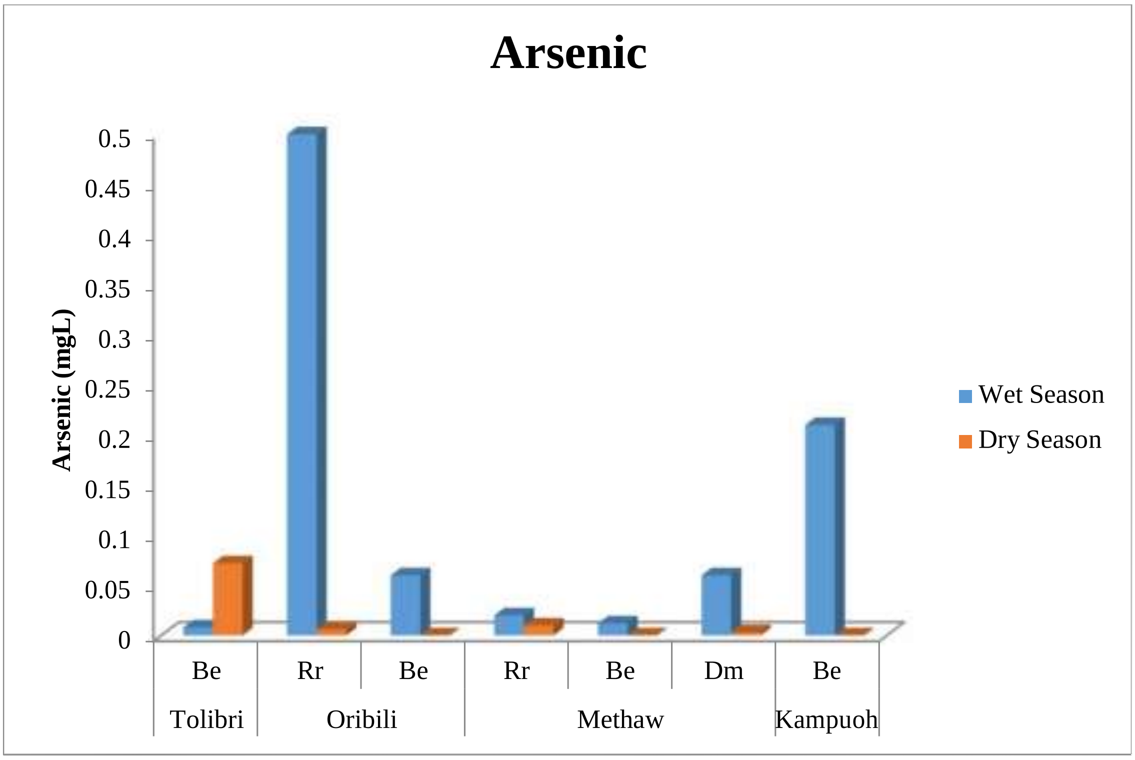

Figure 4.15 Mean Arsenic Values (Be - Borehole; Rr - River; Dm - Dam)

There is no statistically significant difference among the water sources for Arsenic (Kruskal-Wallis statistics = 0.77 df = 2, p-value > 0.05). Mean Arsenic for borehole (0.04±0.06) is higher than river (0.16 ±0.4) and dam (0.03 ±0.04) (Table 4.9).

Table 4.9 Mean Arsenic and Standard Error for Sources of water.

Water source	**Arsenic(±SE)**
Borehole	0.04±0.02
Dam	0.03 ±0.02
River	0.16±0.13

4.5 Community Perception of water quality of the main water source

The perception of water quality varies significantly among the communities. The perception of water colour (Kruskal-Wallis statistics = 29.102, p-value < 0.0001), smell (Kruskal-Wallis statistics = 27.612, p-value < 0.0001) and taste (Kruskal-Wallis statistics = 29.783, p-value < 0.0001) vary significantly among the respondents of the communities (Table 4-1). Methaw, Oribili and Tolibri communities similarly perceived the colour, smell and taste of water from the borehole, their main water source, as being of excellent quality, while Kampuoh community members perceived the borehole water as being of good quality.. However, the perception of water colour (W = 3426.5, p-value = 0.31), smell (W = 3488.5, p-value = 0.21) and taste (W = 3539.5, p-value = 0.15) quality is not affected by the gender.

Table 4.10 Perception of water quality by the surveyed communities

Community	Indicators of water quality*		
	Colour	Smell	Taste
Kampuoh	4±0.11[a]	4±0.11[c]	4±0.12[e]
Methaw	5±0.08[b]	5±0.08[d]	5±0.08[f]
Oribili	5±0.09[b]	5±0.09[d]	5±0.09[f]
Tolibri	5±0.11[b]	5±0.11[d]	5±0.11[f]

* Values represent median scores ± standard error; values with the same alphabetic letters are not significantly different (>0.05); where 4 indicates very good and 5 indicates excellent perception of water quality.

4.6 Major water uses in the District

The third objective of the study is to identify the major uses of water the study area. The various users of water classified are the households, irrigation farmers and livestock herders. In the households, water is used for domestic activities including bathing, washing of cloths, cooking and cleaning. All the respondents indicated that the households are a major water user (Figure 4-16). According to the 80 percent of the respondents, livestock herders use water for the upkeep of their animals, whilst 34.4 percent of the respondents identified irrigation farmers as another group whose activities rely on water.

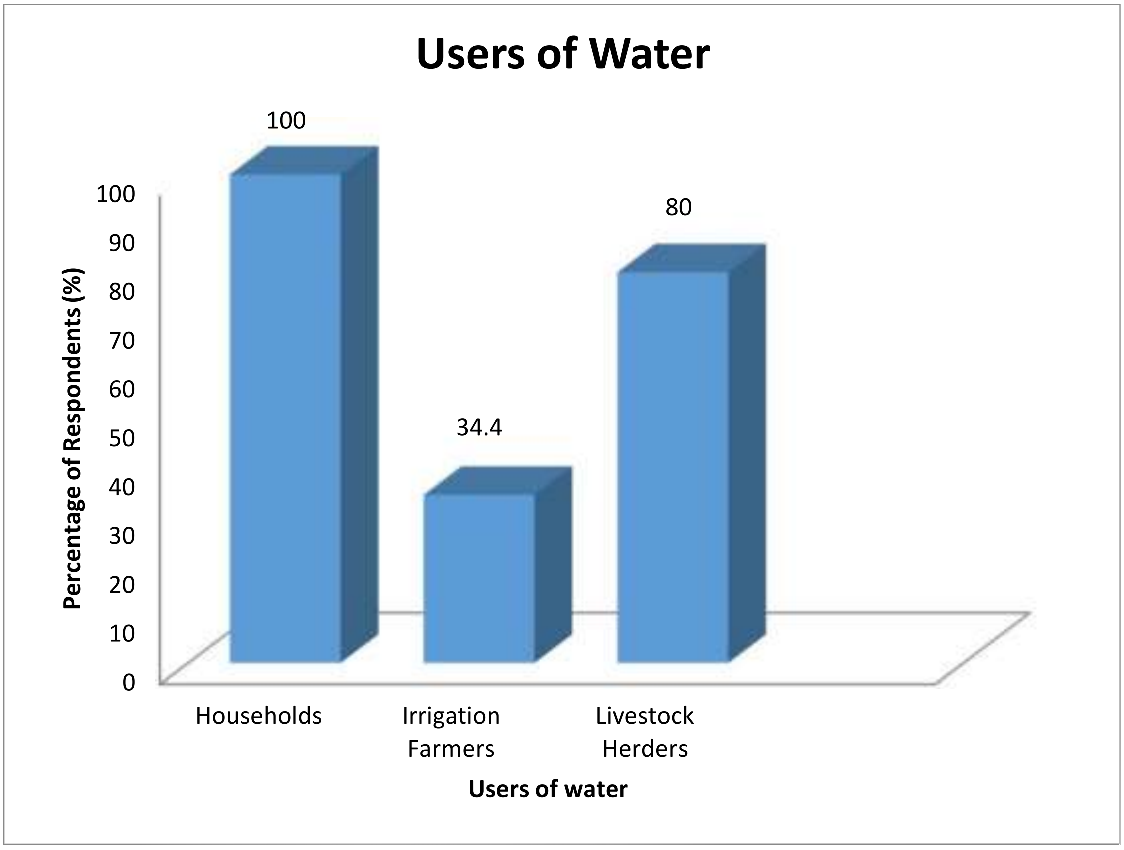

Figure 4.16 Major groups of water users

For the various sources of water and their uses household use is classified under domestic use and construction (Figure 4-17). The borehole dominates all the uses mentioned by the respondents, with the exception of irrigation. According to 40 percent of the respondents, the rivers/streams are used for irrigation. Other sources of water for irrigation are the dams (17.5 percent) and dugouts (1.3 percent). For the provision of water to livestock, the borehole is mostly (90.6 percent) relied on as compared to the other sources. The borehole is also a source of water for construction of houses, according to 55.6 percent of the respondents.

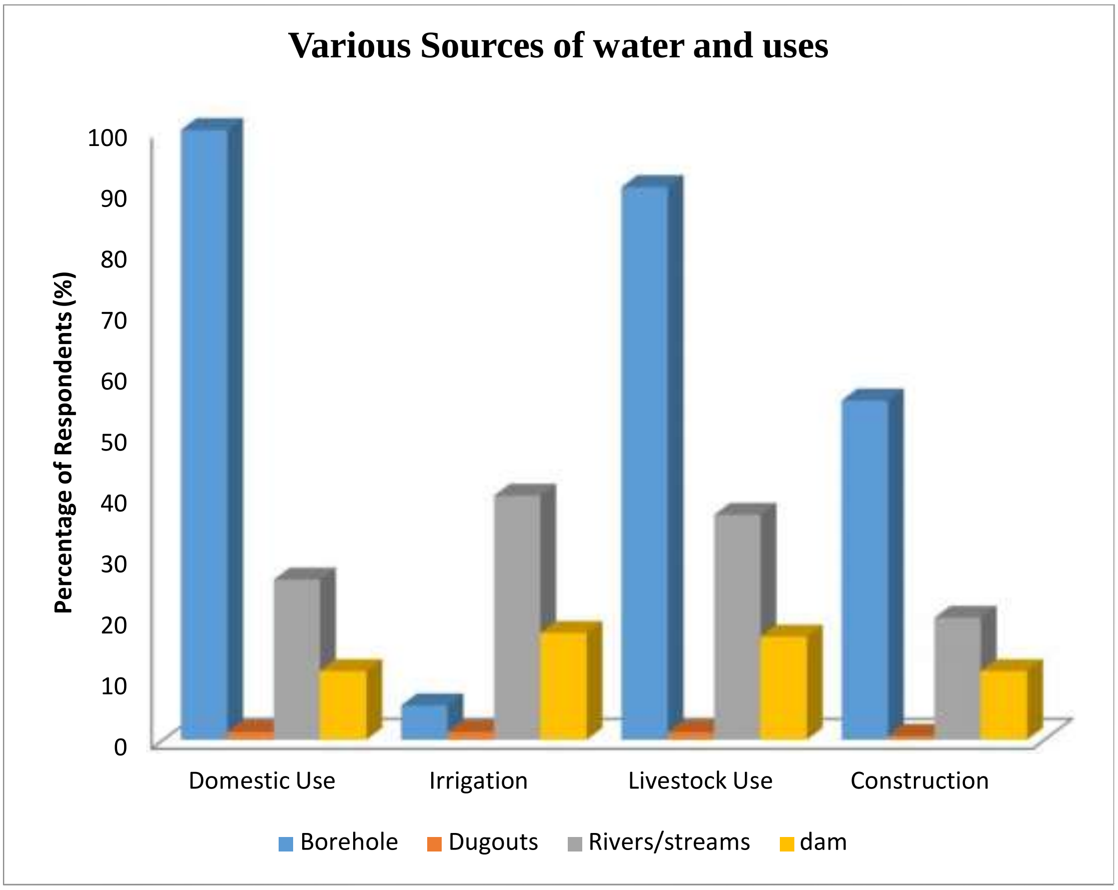

Figure 4.17 Sources of water and their uses.

4.7 Causes of water related conflicts in the area

From the survey, the number of conflicts recorded in the past 15 years was higher than the number reported in more recent times (Table 4-10). However, 19 percent of the respondents deduce that there will be an increase in water related conflicts in the future by 11.5 percent.

Respondents from Tolibri community reported more water related conflicts as compared to other communities, for both the past 15 years as well as presently. Methaw recorded no current water related conflicts. Tolibri had the highest number of respondents (8.1 percent) indicating the likelihood of future water related conflicts occurring.

Table 4.9 Communities conflict trend according to the Respondents

Community	Past conflict (percent)	Current Conflicts (percent)	Future Conflicts (percent)
Tolibri	13.1	5.6	8.1
Oribili	8.1	1.3	3.1
Kampuoh	11.9	0.6	5.0
Methaw	11.2	0	2.5
Total	44.3	7.5	18.7

The main causes of conflicts in the past involved jumping ahead of queues formed at the boreholes (23.3 percent), non-payment of maintenance fees by some community members (17 percent,), ruminants destroying gardens (19 percent) and inadequate number of boreholes (0.6 percent). The current cause of conflict is jumping ahead of queues at the boreholes.

The result of Logistic regression testing the effect of community, gender, number of water sources (available or accessible for a household), distance to the main water source (as measured by time spent to get to the main water source) and time spent in the community, on the probability of occurrence of water related conflicts in the past 15 years and in the present is represented in Table 4-11. According to the data, the likelihood that a respondent has experienced a water related conflict in the past 15 years is not affected by his/her gender, number of water source available or accessible to him/her, how many time he/she has spent in the community, distance to his/her main water source, and does not vary among the communities ($p>0.05$). Similarly, the likelihood of a respondent to currently experience a water related conflict is not affected by his/her gender, number of water sources available or accessible to him/her, how much time he/she has spent in the community, distance to his/her main water source ($p>0.05$). However, the likelihood to currently experience water related conflict varies significantly among the community ($p<0.05$).

Table 4.12 Conflict analysis

	Occurrence of water related conflicts in the past 15 years		Occurrence of water related conflicts currently	
	z-value	*p-value*	*z-value*	*p-value*
Community	0.45	0.65	2.25	0.025*
Gender	0.02	0.99	1.0	0.32
Distance to water source	-0.21	0.83	-0.16	0.87
Time spent in the community	-0.53	0.6	-0.96	0.34
Number of water sources	0.20	0.84	0.37	0.71

*p < 0.05; other p-values are non-significant (>0.05)

4.8 Conflict Curbing Measures

In response to conflicts in the study area, the respondents indicated that there are various mechanisms employed to manage or eradicate this (Figure 4-18). Compulsory queuing was the main measure mentioned by 57.5 percent of the respondents, while redesigning of boreholes was the least, as indicated by 0.6 percent of the respondents. Other measures were mentioned, such as obligated fencing of gardens by all irrigation farmers (23.8 percent). Controlling of ruminants (12.5 percent), and imposing of fines on those who cause conflicts (50 percent). About 5.6 percent of the respondents did not know any curbing measures used.

Figure 4.18 Conflict curbing strategies

Across the individual communities, table 4.12 shows the percentage of respondents who stated various curbing measures stated above.

Table 4.13: Curbing measures to minimise water related conflicts

Curbing Measure	Kampuoh (percent)	Oribili (percent)	Tolibri (percent)	Methaw (percent)
Imposing fines	95.0	40.0	37.5	27.5
Compulsory queuing	55.0	40.0	50.0	85.0
Herding flock	0	15.0	5.0	32.5
Compulsory fencing of garden	0	42.5	7.5	45.0
Redesigning of boreholes	0	0	2.5	0
I do not know	12.5	7.5	15	0

4.9 Water Management Strategies

A number of water management practices are employed by the communities in the study area (Figure 4.19). The most common is regular cleaning of boreholes (55.6 percent) whilst no bush burning and no farming upstream were the least (0.6 percent).

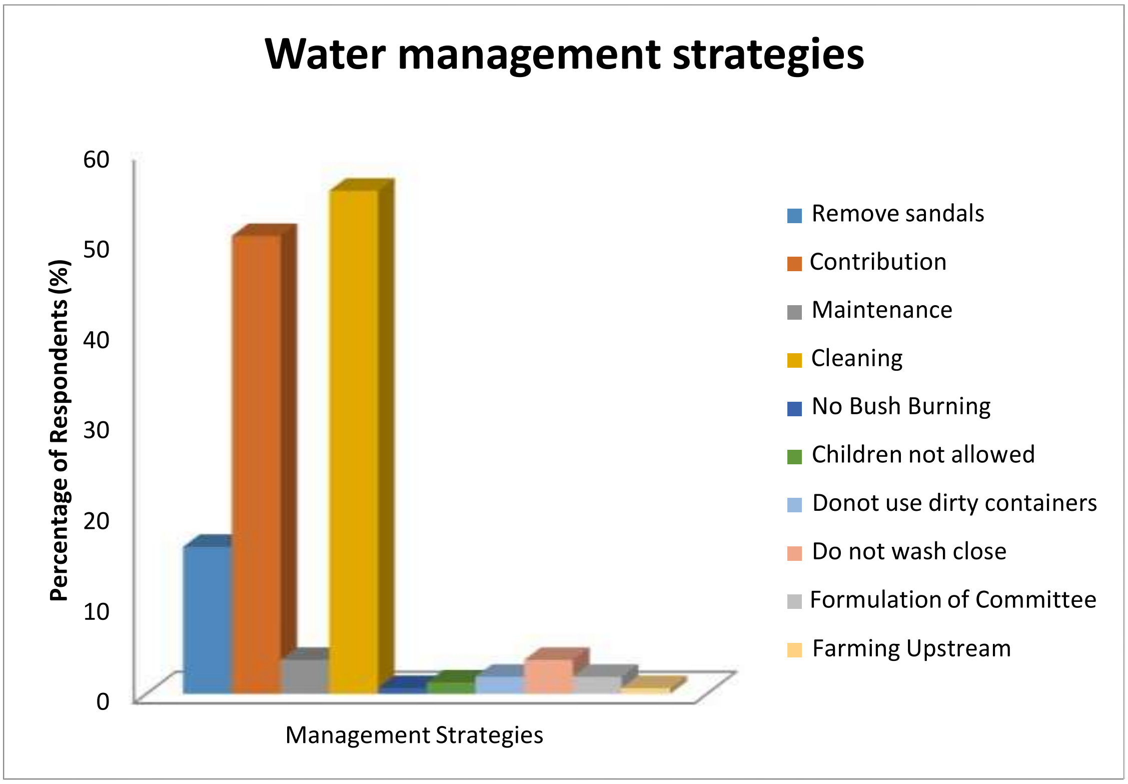

Figure 4.19 Types of water management strategies

Across the communities, contribution towards maintenance, regular cleaning of the boreholes are the two major management strategies which were mentioned by more than half of the respondents in Kampuoh, Oribili, Tolibri and Methaw.

Table 4.13 Management strategies across communities

MANAGEMENT STRATEGIES	Kampuoh (percent)	Oribili (percent)	Tolibri (percent)	Methaw (percent)
Remove sandals whilst on the borehole	10.0	15.0	25.0	10.0
Contribution towards maintenance	50.0	57.5	25.0	5.0
Maintenance regularly	0	5	10.0	0
Cleaning regularly of source	50.0	42.5	65.0	65.0
No Bush Burning	2.5	0	0	0
Children not allowed at sources	0	2.50	0	2.5
Do not use dirty containers in fetching water	0	7.5	0	0
Do not wash close to the source	12.5	0	2.5	0
Formulation of water Committee	0	5.0	0	2.5
Not Farming Upstream	0	0	0	2.5

CHAPTER FIVE

DISCUSSION

5.1 Perception of climate change and water

In addressing climate change, the perception of the indigenous people, the way they think and behave in relation to climate change plays a very significant role (Doss, , & Morris, 2001). Two extreme weather conditions linked to precipitation (rainfall) were identified by the four communities of the study area - droughts and floods. For the past fifteen (15) years, the four communities in the District have experienced either drought or flood annually, or both depending on the time of the year. A study conducted in the Sekyedumase District of the Ashanti Region on the extent of climate change impacts awareness and level of adaptation by famers indicated that farmers do perceive climate change in relation to weather extremes (Fosu-Mensah *et al.*, 2012), as observed in this study.

Various traditional beliefs are attached to the occurrence of the erratic weather occurrences. From the survey, a male farmer in Kampuoh indicated that the gods are responsible for the occurrence of both weather extremes. This ideology was also raised in the women's focus group discussion in Methaw and Kampuoh. Other causes mentioned included cutting down trees and bush burning. Rain recharges the water reserves thus when there is drought, water becomes a scarce commodity. Most rivers and dams dry up and some boreholes malfunction. A female farmer attributes the malfunctioning of the boreholes to the reduction in the water table.

5.2 Sources of water

There are similarities in the various sources of water in the study area and along the Volta Basin, including boreholes, wells, rivers and pipe are being used by respondents for various activities (Engel *et al.*, 2005). In this study, the sources of water vary from community to community, three major sources: boreholes, rivers and a dam were identified. These are similar to results by Gyamfi (2012) in the same study area who identified boreholes, dugouts and the Black Volta River as the sources of water. A female respondent in Methaw indicated that dugouts are resorted to when the major sources of water are unavailable.

According to the World Health Organisation, households have basic drinking water access when they use water from an improved source with a total collection period of 5-30 minutes (a distance of 100-1000m) for a round trip including queuing (WHO/UNICIEF, 2012). In the Upper West Region, 85 percent of the respondents have access to water as per the WHO guidelines, meaning that they live within 1 km from the water source (Gyamfi, 2012). From the study, more than 50 percent of the respondents use more than 30 minutes for a round trip to fetch water. Long queues as well as insufficient sources of water can be attributed to be a cause of delays. In Ga East Municipality located in the southern part of Ghana, for example, more than 30 percent of the respondents spend more than 30 minutes in a round trip to fetch water, including queuing (Essien, 2014). Many communities rely on boreholes as the major source of water, even though other sources are identified.

5.3 Water quality

Climate projections and observational records have provided evidence that freshwater resources all over Africa are vulnerable and have the potential to be strongly impacted by climate change, which have impacts on the ecosystem (Algamal, 2011). The physiochemical parameters are discussed in reference to the World Health Organisation (WHO) guidelines for drinking water and the Ghana Standard Authority(Ghana Standard Authority, 2013). Generally, the boreholes are considered to be of better quality as compared to the Black Volta River and dam. Boreholes are usually not exposed to runoffs and undergo some form of filtration underground. A farmer classified the borehole water to be of a very good quality although the flow changes with the seasons. It was also observed that during the dry season, the recharge of the ground water is highly limited reducing the water table levels.

5.3.1 pH

The pH of water for drinking should be between 6.5- 8.5 according to the WHO (2004) guidelines. Low pH values in drinking water is not known to have any direct health risks to individuals, but can corrode metals like lead, copper and zinc used for plumbing to channel the water (Patil *et al.*, 2012; Rossiter *et al.*,2010). Not all the pH values in the study samples were within the acceptable range. The high acidity recorded for almost all the boreholes in the study is corroborated by an extensive work done on chemical drinking water in Ghana, which established that 50 percent of the water tested in the country was acidic (Rossitee *et al.*, 2010). This is attributed to granite based rocks with low buffering capacity and the type of soils underground. However, since plastic containers dominate households for water storage, there are minimal health risks to the consumers since the plastic does not leach.

Generally, the individual pH values were lower in the wet season as compared to the dry season, as also reported by Braimah (2013) who observed that individual pH values were generally lower during the rainy season in Wa due to dilution, but there were no statistically significant differences. Other studies have, however, observed decreasing pH with increasing rains as a result of the geological nature of the area (Atobatele & Ugwumba, 2008).

5.3.2 Temperature

There are no recommended guideline values for the temperature of drinking water although increases or decreases affect the composition and reactions in water. High temperatures increase the rate at which water dissolves substances, especially rocks, increasing the levels of conductivity and total dissolved salts. Higher temperatures cause the multiplication of bacteria and coli form to temperature (37°C) (Sakyi & Asare, 2012). Generally, the temperatures in the rainy season 22.7°C at Oribili and Tolibri to 31.63°C in Methaw were lower than the dry season (24°C at Oribili to 32°C at Kampuoh) which may reflect the ambient air temperatures during the respective seasons. The mean temperature of water samples obtained from boreholes and hand-dug wells in the study communities was low even though the borehole temperatures were slightly higher than the hand-dug wells, but not statistically significant.

5.3.3 Conductivity

According to WHO (2006), electrical conductivity of water above 300μS/cm can affect its suitability for domestic use. All water samples taken for both dry and wet seasons were within the acceptable limits for conductivity. Conductivity of water in the boreholes for all communities recorded higher conductivity values due to high levels of soluble salts comprising of anions and cations in the surrounding sediment and soil (Jobbágy & Jackson, 2007). Conductivity recorded in the dam and river was low and may be attributed to high temperatures. The level of the temperature of the water affects the mobility of the ions in the water (Whitehead *et al*., 2009). Abdulai (2014) in his study on farm waste and nitrate pollution established that low inflows and high temperature in the dry season decreases the conductivity of dam water.

5.3.4 Total Dissolved Solids

According to the Ghana Standards Authority (2013) and the World Health Organization (2004), the highest limit of total dissolved salts for drinking water is 1000 mg/L. Concentrations higher than 1200 mg/L can cause the water to taste unpleasant and cause corrosion (Howard *et al*., 2003). In Ghana, recorded TDS values in water samples range from 4.963 mg/L to 1454 mg/L (Rossiter *et al.*, 2010), as compared to the study sites where all the recorded TDS values were within the standards (10 mg/L - 140 mg/L). There has been no direct health risks associated with drinking water with TDS concentration below or beyond the acceptable limits (Rossiter *et al*., 2010). The TDS values for the boreholes recorded higher figures as compared to the water samples taken from the other sources. This could be attributed to the faster rate of solubility of minerals in underground.

5.3.5 Turbidity

The standard for turbidity in drinking water is less than 5 NTU (GSA, 2013) and less than 1000 mg/L according to the World Health Organisation. All the values recorded for water sources in the study sites were within limits, except for the dam in Methaw during the dry season (12125 mg/L). During the sampling period, the dam was almost dried up and the water was muddy and thick which influenced the very high value recorded. The borehole water samples recorded the least values, attributable to the natural filtration processes that ground water naturally undergoes. In Ghana, national turbidity range from 0 NTU to 629.7 NTU (Rossiter *et al*.,2010); with other surveys conducted in the Pong-Tamale and Nanton in the Northern Region of Ghana indicating that borehole, hand dug wells and pipe borne water were generally within the acceptable guideline value, whilst water from the dams of Pong-Tamale, Savelugu and Nanton had the highest turbidity (Abdulai, 2014). During the dry season, with higher rates of evapo-transpiration, the water levels in the dam quickly reduce leaving behind highly concentrated patches of water. Animals that drink from dams and rivers also disturb the soils, leading to increased turbidity of the water.

5.3.6 Iron

Iron is a very common metal and may detected in drinking water due its occurrence in the local geology of an area or the corrosion of iron in pipes used to channel water to consumers (WHO, 2006). Drilling records have revealed that on the average, about 20% of boreholes drilled for domestic water supplies contain high concentrations of iron above the Ghana Standards Board permissible limits of 0-0.3 mg/L for domestic water. Iron levels in drinking water should not exceed 0.3 mg/L (Ghana Standard Authority, 2013) as the taste is affected. In Ghana, iron concentrations are generally low, less than 0.3 mg/L, although high levels of up to 4.257 mg/L have been found along the coast, inland forested areas and the Northern Region (Rossiter *et al*., 2010). In the study, iron levels recorded ranged from below detection to 12.20 mg/L as compared to similar study by Abdulai (2014) where iron levels in the water samples from the borehole were within the acceptable limits (below detection to 0.0004 mg/L). In the dry season, water samples from the dam in Methaw and the river along Methaw and Oribili were all above the acceptable limits. Various forms of irrigation farming were observed along the rivers which may contribute to the high levels of iron measured in the river water samples.

5.3.7 Arsenic

Arsenic (As) levels in the study ranged from 0.0001 mg/L to 0.5000 mg/L, compared to the WHO guideline value of 10 µg/L (0.01 mg/L). In Ghana, as levels exceeding this standard were observed in the Ashanti Region, around Obuasi, the north of the Volta Region and in the Upper East. This can be associated with the areas geochemistry and its mobility during weathering conditions, especially in gold mining areas (Rossiter *et al*., 2010). The highest arsenic value of 170 µg/L was recorded in Bolgatanga, an active mining area which may release naturally occurring (Rossiter *et* *al*., 2010) as compared to no detection in water samples at Mpohor in the Western Region of Ghana (Bedu-Mensah, 2014). Irrigation activities also are means by which arsenic is transferred into water bodies, especially the river and dam. The use of fertilizer and pesticides on farms aid in the transfer of arsenic into water. Runoffs or leaching are two processes by which the transfer can occur.

5.3.8 Nitrate

Surface water nitrate concentrations can change rapidly owing to the surface runoffs of fertilizer, uptake by phytoplankton and denitrification by bacteria, but groundwater concentrations generally show relatively slow changes (WHO, 2011). Nitrates have been listed as the second greatest chemical threat to surface and ground water in the world (Haller *et al*., Undated.). Generally all the samples obtained from the various water sources recorded nitrate concentrations below the WHO Guideline of 10 mg/L, except for the river in Oribili (12.8 mg/L). Significant concentrations of nitrate were measured in the samples because this area is a farming zone where compound farming is dominantly practised. The farms were observed to be very close to most of the water sources, especially the boreholes. The use of fertilizers also may result in the significant levels nitrate in the water samples through leaching or runoff processes from the farms into the surface waters. During the dry season, the nitrate concentrations in the Black Volta River also increased significantly in water bodies in both Methaw and Oribili communities. .

5.3.9 Phosphate

Phosphorus is normally low (< 1 mg/l) in clean potable water sources and usually not regulated (Abdulai, 2014; Nduka *et al*., 2008). The Black Volta River in Oribili and Methaw recorded very low phosphate concentrations (0.24 mg/L and 0.47 mg/L, respectively), as compared to the boreholes (0 mg/L – 1.62 mg/L) for both seasons.

Throughout the country, various concentrations of phosphate have been recorded, with low values in the Mpohor-Fiase District (Bedu-Mensah, 2014) Bedu-Mensah, 2014)to values between < 0.100 - 1.214 mg/L (Rossiter *et al*., 2010)

5.4 Uses of water

In Ghana, majority of households use several sources of water for one activity, and water from one source is typically used for several activities (Engel et al., 2005). The major uses of water identified include domestic use, irrigation, livestock use and construction, which are used for various activities. Gyamfi (2012) identified irrigation, livestock watering and domestic activities as the main uses of water in the same study area. This confirms the uses identified except for the construction purposes.

The boreholes are heavily relied on for house hold duties. These include washing, bathing drinking and cooking. Due to the insufficient numbers of reliable sources of quality water, the boreholes are normally not used for irrigation purposes. Domestic use is given the most priority as compared to the others. In a study by Gyamfi (2012), the borehole was relied on by 100 percent of the respondents, similar to this study in the same area.

The rivers and dams are used for irrigation purposes mostly in the study area, especially the Black Volta River (Gyamfi, 2012). However, in some communities like Tanduori in the same region, borehole water is highly relied on for irrigation due to sensitization programmes by Care International, an NGO, on the impacts of farming at river banks. Akenten (2012) reported that the main sources of water for irrigation by farmers is the stream/river (90 percent of the respondents), with eight (8) percent depending on well/borehole for irrigation and two (2) percent on reservoirs. Irrigation is a major adaptation process in agriculture, hence the increasing numbers of farmers in that sector (Deressa *et al*., 2011).

Livestock like goats, sheep and cattle also require watering. In the study, over 90 percent of the respondents rely on boreholes for watering their livestock. According to a respondent in a focus group discussion, this was due to the long distances between the settlements and the rivers and dam. Some animals get lost when allowed to stray in search of water. However, cattle go to the river to satisfy their water requirements. A study conducted by Along the Black Volta Basin, small ruminants like goats and sheep rely on water from dugouts and small reservoirs, but occasionally use rivers, streams and water trough of boreholes, while livestock such as cattle donkey and horses water from rivers and sometimes small reservoirs (Akandi, 2013).

5.5 Drivers of Conflict

The extent of water related conflicts vary from community to community. Tolibri community has reported more water conflicts as compared to the other communities, as the community has only one borehole as their main source of water and has a high population. The tendency not to heed to the first come first serve principle is very high. Also, from focus group discussions, farmers interested in irrigation farming will have to acquire plots of land close to the Black Volta or dam in Methaw.

Another source of conflicts is between the garden owners and the livestock owners during the dry season period where livestock are allowed to stray in search of feed and often destroy gardens along the dam and rivers that are not properly fenced. Gyamfi (2012) , also identified the conflicts between herdsmen and irrigation farmers in the Upper West Region. A study conducted by Kpéra *et al*. (2012) revealed that conflicts erupt when other users of agro pastoral dams plights are neglected

Due to the long distances involved, effective monitoring is a challenge. Most community members believe that paying of the maintenance fee for the sustainability of the water sources is very important. The payment of water tariffs in the study area as a cause of conflicts (Gyamfi, 2012) and residents who are not able to pay are not allowed to have access to the water. Misunderstandings erupt when defaulters are found in queues for water. This can be associated with poverty and the unwillingness of some local people to pay.

From the research, the occurrence of conflicts has drastically reduced from 15 years ago. However, if proper measures are not implemented, respondents foresee an increase in the occurrence of conflicts in the future. Almost 19 percent of the respondents believe that if the current water challenges, like long queuing due to insufficient sources of portable water are not dealt with, the rate of conflict occurrences will increase in the future.

5.6 Response to water related conflicts

Water related conflicts are encountered when there are multiple users of water along limited water sources (Apipalakul *et al.*, 2015). To help manage or eradicate water related conflicts in the Lawra District, a number of bye-laws have been instituted by the local authorities. Within the district, the traditional authority is highly respected. Compulsory queuing is one of the regulations instituted. From observation, this regulation is widely respected, hence the reduction in the current conflicts observed, even though some exceptions are made when necessary.

Secondly, the imposing of fines is an effective sanction. Most of the people are considered poor, hence it is not prudent to incur avoidable costs. In settling the disputes between ruminant owners and irrigation farmers, the latter are advised to protect their gardens by way of fencing them. Ruminant farmers are to either have their ruminants herded or provide water for them at home. The design of boreholes with troughs that collects excess water during fetching also serves as a remedy. Animals have the opportunity to drink from these troughs without interrupting individuals who are fetching the water.

Conflict resolution is mostly the role of the traditional leaders and the community members. Gyamfi, (2012) in a study in the same area identified traditional leaders as the main conflict resolvers. Monitoring of water use by cooperation of the industry and village representative; arranging the community forum for cooperating on water use and other problems by the community leader, as well as establishing agreements on water use and punishment regulations, which requires a community committee to be established to monitor water are ways of resolving conflict (Apipalakul *et al*., 2015), with some of these already instituted in the Lawra District.

5.7 Water Management Strategies

In the study area, the informal and traditional systems of managing water are more recognised. The traditional system of governance within the Lawra area in the Upper West region is highly recognised and held in high esteem by the local people as compared to the formal systems (Gyamfi, 2012). Formal rules are generally not highly regarded at the local level and decentralization does not mean that local people are enabled to manage their environment especially the agro pastoral dams (Kpéra *et al.*, 2014).

Across all the communities, water and sanitation committees known as WATSAN committees are formed to manage all water related challenges as well as sanitation. They are trained by the District Assembly on cleaning and maintenance of the borehole. However, they are not maintenance experts and repairing malfunctioning boreholes may take very long periods. The lack of technical personnel and poor maintenance have been identified as some of the main challenges facing water supply schemes in Ghana (Rossiter *et al*. 2010; Anokye & Gupta, 2012). Hence, the regular cleaning of the water sources, especially the borehole, is the major strategy in the community. Selected community members are assigned to do the cleaning periodically.

The periodic contribution of money for the maintenance of the water sources is also very important in the study area. After sources of water are provided, they are left in the care of the community members. Contributions are used for regular maintenance, to buy new parts and pay for new parts to replace faulty borehole parts. The amount contributed varies from community to community. One key maintenance and management strategy is that children are not allowed to play with the boreholes. Others include not washing in dugouts, payment of fees for maintenance of domestic water sources, prohibition of water livestock in water sources and the cleaning of the cisterns at the boreholes, Some informal measures instituted for the protections of the agro pastoral dams include prohibitions on washing and swimming in the dams, with washing allowed only downstream of the dams (Kpéra *et al*., 2014).

The traditional leaders spearhead most activities and engage in conflict resolutions. The community members are the water users and a selected number of them form the WATSAN committees to manage water issues after they have been trained by the District Assembly. The District Assembly, Care International, Environmental Protection Agency through the GEMP project, Pronet North and the Catholic Church are major stakeholders who are infrastructural implementers within the study area

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The objective of the research is to assess the nature of competing uses of water and identify sustainable ways of improving water management in the Lawra District to reduce water related conflicts. The District has various sources of water which have multiple purposes. The identified major sources of water include Boreholes, Dams and rivers. Other sources like the dugouts are resorted to in times of scarcity of water. The results from the survey indicate that more than fifty percent of the respondents still do not have access to quality water. They spent more than 30 minutes to access water in a round trip including queuing.

It can be concluded that, the various sources of water have varied quality and the boreholes which are the most preferred are considered to be of the higher quality as compared to the other sources of water identified. The quality of the water source determines the stipulated use. The various uses are classified as domestic use which includes bathing and cooking. The two other significant uses are irrigation farming and livestock use. Widely, irrigation is done at the banks if the Black Volta River and the dam. The livestock rely mostly on the sources of water to meet their requirements. In competing for water among the users, some forms of conflict erupt. There are conflicts that erupt at the boreholes either because of the non-payment of maintenance fee by some people or the jumping of queues by women. Another identified conflict is between irrigation farmers and livestock herders at the rivers and dam when ruminants destroy gardens along the river or dam. The occurrence of conflicts in the last fifteen years have reduced currently but has the tendency to increase again if current water related conflicts are not mitigated. The mitigation measures mentioned include compulsory queuing and redesigning of boreholes to include a trough, Compulsory fencing of gardens, controlling of ruminants and imposing of fines on those who cause conflicts.

The water management strategies put in place include the removal of sandals whilst on the borehole, Contribution towards maintenance, regular maintenance, Cleaning regularly of source, No Bush Burning, Children not allowed at sources, No dirty containers used in fetching water, Not washing close to the source, Formulation of water Committee and Not Farming Upstream.

In conclusion, there is a high competition for water in the dry season hence inducing conflicts among users. Even though the community members through their traditional rulers have been able to respond and manage water crisis, more sources of water need to be provided.

6.2 Recommendation

The challenges in sustainable management and use of water can only be addressed in a holistic manner. Below are some recommendations to enhance water use and water management within the study area.

- Community members need to be educated on their water quality issues and related health hazards and where practically possible. The government of Ghana should invest in water infrastructure operations and maintenance to improve the access of quality water to various communities. The boreholes which are the most reliable source of water for all community members should be constructed well to ensure its efficiency.
- Climate adaptation strategies must be locally specific, such that they relate to the local environmental context and are sensitive to local cultures and lifestyles, and resources and expertise need to be deployed to facilitate local

actions. People in the semi- arid area have existing water management and adaptation practices. Governments should integrate these existing strategies and policies to counteract the impact of global and climate change in their development plans and programmes. Since most the farmers are interested in the dry season farming to bridge the prolonged hunger, efficient dam building and water-harvesting systems should be instituted.

- The government should strengthen research on the link on climate change and water resources and associated conflicts. The improvement of research results to be understood and helpful to the peoples living in such areas is highly important. Monitoring and research priorities as well as capacity building at all levels should be fully considered, especially the involvement of citizens in scientific water monitoring activities.
- The integration of meteorological monitoring, remote sensing data and enhanced investment in forecasting capabilities can further inform climate change adaptation strategies. The Government should work on the improvement of the hydro-climatic monitoring networks to improve the observation and understanding of climate change. The necessary infrastructure should be provided to the appropriate industries to provide timely and free access of data and information. Especially with particular emphasis on rainfall patterns and their resultant hydrological responses so as to identify adequate adaptation strategies and their timely implementation.

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APPENDICES

Appendix A

Location of sampling water sites (GPS readings)

Code/ID	Sampling sites	GPS (North)	GPS (West)
O1	Oribili 1	N $10^0$40.726	002^0 53.759
O2	Oribili 2	10^0 41.200	002^0 53.576
OR2	Oribili 3	10^0 40.901	002^0 54.350
OR1	Oribili 4	$10^0$40.925	$002^0$54.361
OR3	Oribili 5	$10^0$40.873	002^0 54.352
T1	Tolibri 6	$10^0$35.141	$002^0$52.861
T2	Tolibri 7	$10^0$34.894 $10^0$34.902	$002^0$53.237
T3	Tolibri 8	$10^0$34.902	$002^0$53.385
T4	Tolibri 9	$10^0$34.802	$002^0$53.470
M1	Methaw	10 ^{0}34.641	002^0 53.740
M2	Methaw	$10^0$34.404	$002^0$53.965
M3	Methaw	$10^0$33.896	$002^0$54.222
MR1	Methaw	10 ^{0}33.896	$002^0$54.716
MR2	Methaw	$10^0$33.857	$002^0$54.682
MR3	Methaw	$10^0$33.765	$002^0$54.651
MD1	Methaw	$10^0$34.273	$002^0$53.665

MD2	Methaw	$10^0$34.244	$002^0$53.647
MD3	Methaw	$10^0$34.259	$002^0$53.609
KM1	Kampuoh	10^0 36.300	$002^0$51.378

Appendix B

Questionnaire

University of Ghana

Faculty of Science

Environmental Science Programme

QUESTIONNAIRE ON EXPLORING THE COMPETING USES OF WATER IN THE CONTEXT OF CLIMATE VARIABILITY AND CHANGE IN THE LAWRA DISTRICT

Questionnaire Administration

This questionnaire is being administered to the residents of the Lawra district to assess adaptation measures involved in shared water use within the district.

The questionnaire is a partial requirement for the award of master of philosophy degree in environmental science. All information is therefore for academic purpose and will be treated confidently. Your genuine response is required. Please indicate your answers by ticking and specify by writing where necessary.

Interview Date

Questionnaire no..

Interviewer..

Locality...

Section A: Demographic information of respondent

1. Gender of respondent. A. Male() B. Female()
2. Age group of respondent. A. <20 () B. 20-29() C. 30-39() D. 40-49 () E. 50-59 () F. 60+ ()
3. Marital status of the Respondent A. Married () B. Single () C. Widow/Widower () D. Divorce ()

4. Educational background A. Primary () B. Secondary C. Tertiary () D. None () E. Other specify.....................................
5. How long have you been staying in this community? A. <5 yrs () B. 5-10yrs C. 11-15yrs D. 16-20yrs E.> 20.
6. Where did you come from and why?

   ....

   ....

   ....

   ....
7. Is the respondent the head of the household? (If man is away >6months/yr, then woman is head)? A. Yes () B. No ()
8. How many persons are currently present in this household? Total: [……] Male: [......] Female: [……]
9. How many persons in this household have travelled out of the community currently? Total: [……] Male: [......] Female: [……]
10. How many of the household member are less than 18 years of age? Total: [.......] Male: [.......] Female: [........]
11. What do you do for a living? A. Farmer () B. Trader () C. Both () D. Others () Specify...
12. Do you receive additional support? A. Yes () B. No () If Yes specify who and what?

    ....

    ....

    ....
13. List some assets you can afford?

a) .... b) ....

c) ....

d) ....

e) ....

f) ....

Section B Location of water sources

14. What are the sources of water for your household?

A. Wells () B. Borehole () C. Dugout () D. Stream/River () E. Others specify...

15. How much time does it take to leave the house, fetch water and return home? Please tick the correct answer

Water source	**0-30mins**	**30mins-1hour**	**1-1:30 hours**	**1:30-2 hours**	**>2hours**
Wells					
Boreholes					
Dugouts					
Streams/ rivers					
Other specify					

16. Are there any factors that affect the time given in question #15?

....

....

....

17. How long has the water source been in use?

A. < 5yrs () B.5-10 yrs () C. 11-15 yrs () D.16-20 yrs () E. > 21yrs ()

18. Has the quantity changed over the years? A. Yes () B. No () C. I don't know ()

If yes, specify how and when...

....

....

....

19. How do you store water? A. Metal containers () B. Earthenware () C. Plastic containers () D. Concrete containers () E. Others (specify)........................

20. Are there any environmental changes in the past 15 years that has affected the quality or quantity of water?

....

....

....

....

Section C: Water Quality

21. Please grade the following parameters as;
1=Very bad, 2=Bad, 3=Good, 4=Very Good, 5=Excellent, 6=I don't know

Water source	**Colour**						**Smell**						**Taste**					
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
Pipe borne																		
Borehole																		
Wells																		
Dug out																		
Dams																		
River/stream																		
Other, specify;																		

22. What do you think may account for the colour, smell and taste of the water if any?

Water source		*Please tick the correct response*					
		Agricultural activities	Dumping of waste	Minerals in water	Human waste	I don't know	Other (specify)
Pipe borne	colour						
	smell						
	taste						

Borehole	colour						
	smell						
	taste						
Wells	colour						
	smell						
	taste						
Dug out	colour						
	smell						
	taste						
dams	colour						
	smell						
	taste						
River/stream	colour						
	smell						
	taste						
Other, specify;	colour						
	smell						
	taste						

23. Have you ever suffered from any disease you suspect to be caused by your source of drinking water? A. Yes () B. No ()

24. If yes what disease is it? ....

25. How did you manage the disease?

....

....

....

....

Section D; various water users

26. Who are the various users of the water in the community?

A. households () B. Irrigation farmers () C. Livestock herders () D. Multiple users.

E. Others Specify..

27. What is the water used for?

Water source	Uses			
	Domestic	Irrigation	Livestock rearing	Other specify;
Pipe borne				
Borehole				
Wells				
Rivers/ streams				
dugouts				
Others specify:				

28. Who is responsible for gathering water for household use and why? ....

29. What informs your choice of water source? A. Affordability () B. Distance () C. Availability () D. Others Specify................

30. Which of the water sources is your primary sources and why?

....

....

....

31. How often do you fetch water? A. Once a day () B. Twice a Day () C. Three times a day () D. Every other day () E. Other (specify)......................

32. Are there any specific groups of people restricted from having access to any of the water sources? A. Yes () B. No () C. I don't know ()
Specify why indicating which groups and which water sources

a. ....

b. ....

c. ....

d. ....

Section E: Water use conflicts

33. Have there been any water related conflicts in the past 15 years? A. Yes () B. No ()
34. How long did the conflict last if Yes in 33 above, specify...
35. In your opinion what caused the water related conflicts in question # 34?

    Specify..

36. Which group of people were involved in the water related conflict?

    Specify..

37. Are there any current water related conflicts? A. Yes () B. No ()

    If Yes what are the causes?

    ....

38. Do you foresee any water related conflicts in the near future? A. Yes () B. No ()

    Give

    reasons...

    ....

    ....

39. How has this water related conflict affect your

    livelihood?...

    ....

    ....

Section F: Responses to water stress and related conflicts

40. How do you respond to water scarcity?...

....

....

....

41. Is the strategy stated in question #40 successful? A. Yes () B. No ()

Why?..

....

42. How effective do you think the water related conflict curbing measures are?

*formal= governmental regulations

*informal= community based regulations

Curbing measure (formal)	*Not effective*	*Effective*	*Very effective*	*I don't know*

Curbing measure (informal)	*Not effective*	*Effective*	*Very effective*	*I don't know*

Section G; Formal and informal structures in place

43. Are there structures in place for managing the water body? A. Yes () B. No ()

What are the structures in place for managing the water resource? Tick the following level of effectiveness in the table below: *formal= governmental regulations

*informal= community based regulations

1=Not effective; 2=Effective; 3=very effective; 4=I don't know

Date of passing	***Structure in place***		**Level**			
	Formal	***Stakeholder***	**1**	**2**	**3**	**4**

Date of passing	***Structure in place***		***Level***			
	Informal	***Stakeholder***	**1**	**2**	**3**	**4**

44. Can any other management strategy be implemented effectively here? A. Yes ()

B. No.

Specify any other strategies and why?...

....

....

....

....

Section H; stakeholders

45. Who are the stakeholders involved in water use management in the community?

Stakeholder	***Role***	***Effectiveness***		
		Ineffective	***Good***	***Excellent***

Appendix C

FOCUS GROUP DISCUSSION GUIDE

Focus Group Discussion Guide

1. Community identification

Questionnaire ID:			Date:
District		Community:	
GPS coordinates	X	Y	Altitude
Facilitator 1			
Facilitator 2			

2. Demographic characteristics

Categories	Total	Males	Females	occupation
Interview group composition				

3. Available water services in the community (multiple choice)

1=borehole 2= Dug out 3= Well 4= Dam 5= stream/ river 6= other (specify): ....

4. What is the water used for?

   a) ....
   b) ....
   c) ....
   d) ....
   e) ....

f) ....

5. Is the water quality good for purposes it's been used for?

6. How many drought situations have been experienced in this community within the last 15 years?

7. How did you respond to the drought situation?

8. How effective were those responses?

9. How many flood situations have been experienced in this community within the last 15 years?

10. How did you respond to the flood situation?

11. What changes have been observed in the weather?

(a)……………………………………..………………........…………………….....

(b)..

12. How do you respond to these existing conditions?

Prevailing condition	Response mechanism

(Most important adaptation strategy rank=1)

13. Are there any difference in response mechanism choices among the women and men?

14. Have you observed any challenges with these response strategies?

15. Are there any future expectations in climatic conditions?

16. Have there been any water related conflicts in the community and why?

17. How did you respond to these water related conflicts?

18. Which of these response measures are most effective and why?

19. Do you foresee any water related measures in the future and why?

20. What are the informal structures of water management?

21. What are the formal structures of managing water?

22. Which of the structures is more effective and why?

23. Who are the stakeholders involved and what how effective are they?