UNIVERSITY OF CAPE COAST

ASSESSMENT OF VULNERABILITY OF ASSETS AND LIVELIHOODS TO CLIMATE VARIABILITY FOR ADAPTATION PLANNING IN A COASTAL COMMUNITY IN GHANA

BY

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ELIZABETH EFFAH

2014

DECLARATION

Candidate's Declaration

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

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

Name…………………………………………………………..

Supervisors' declaration

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

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

Name………………………………………………………….

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

Name…………………………………………………….

ABSTRACT

Since 1970, temperature increase of over 1ºC and reductions in rainfall of approximately 20% have been recorded in Ghana. The aim of the study was to contribute to the processes of adaptation planning to climate variability through the assessment of climate vulnerability in Akwidaa, Ghana. The methodology combined empirical historical data with active community participation and local knowledge. Historical climate data from 1970 to 2012 was collected from the Ghana Meteorological Agency and analyzed for trends using linear regression and anomalies. Data on livelihoods of communities living in Akwidaa were obtained using questionnaires and interviews. The general assumption was that livelihood options and assets in Akwidaa were vulnerable to climate variability and there would still be heavy dependence on farming and fishing. Possible adaptation strategies for Akwidaa were explored with active participation of the locals, district assembly and desk study. The results show that, rainfall in the area has reduced over the past 43 years by approximately 0.2 mm whilst temperature has also increased by 0.02 ºC respectively. Relative humidity in the area has also decreased by 2%, signifying reduction in moisture. Increasing temperatures and decreasing precipitation has also had negative impacts on livelihoods leading to a decline in activities. The community has not coped well with the impacts of climate variability and will need well planned community-based adaptation strategies.

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DEDICATION

This work is dedicated to my mother, Miss Dora Adarkwaah and my father, Mr. William Effah.

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LIST OF ABBREVIATIONS

AR4	Fourth Assessment Report
CH_4	Methane
CFC	Carbon floro carbons
CO_2	Carbon dioxide
EPA	Environmental Protection Agency
FAO	Food and Agricultural Organization
GCM	General Circulation Models
GMA	Ghana Meteorological Agency
GNCCP	Ghana National Climate Change Policy
GHGs-	Greenhouse gases
IPCC	Intergovernmental Panel on Climate Change
IUCN	The World Conservation Union
NO_2	Nitrite
NCCP	National Climate Change Policy
NADMO	National Disaster Management Organization
NAPA	National Adaptation Plan of Action
NCCSAP	Netherlands Government Climate Change Studies Assistance Project
SCM	Simple Climate Models
SEI	Stockholm Environmental Institute
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WRI	World Resources Institute
WMO	World Meteorological Organization

WWF	World Wildlife Fund

CHAPTER ONE
INTRODUCTION

Background to the Study

Studies indicate that the level of carbon dioxide (CO_2) in the atmosphere is increasing at a rate of 0.5% per year (Forster et al., 2007). This rate is about 100 times faster than any change the Earth had experienced during the past 650,000 years (Royal Society, 2005). The process is likely to accelerate in the next decades when the level of carbon dioxide in the atmosphere is expected to reach a level about three times higher than its present value of approximately 400 parts per million [ppm] (IPCC, 2014). This increase in atmospheric CO_2 is primarily caused by anthropogenic emissions of CO_2 from fossil fuel burning and deforestation (Franchito and Rao, 1992). This high level of atmospheric CO_2 as well as that of other greenhouse gases (e.g. CH_4 and NO_2) absorb and re-direct thermal radiation towards the surface of the earth (IPCC, 2014). As a consequence, earth surface temperature has increased by approximately 0.5 to 0.8^oC in the past hundred years (e.g. Hansen et al., 2001; NASA Report, 2006). Over the past 30 years alone, the earth has warmed by ~0.6°C (Hansen et al., 2006), although this varies across continents by ±0.2^oC because of local, regional and seasonal conditions such as El Nino (Hansen, Sato, Ruedy, Lo, Lea and Medina-Elizade, 2006).

Records show that all the five warmest years over the last century occurred in the last ten years, with 2005 temperatures being the warmest (NASA, 2006). The increase in earth surface temperature will cause ocean and land water to evaporate and be moved around with winds in the atmosphere, which can condense to form clouds, and fall back to earth as rain and other forms of precipitation (e.g. snow). Hence, according to the United Nations Intergovernmental Panel on Climate Change Report (IPCC, 2001), changes in rainfall and other forms of precipitation will be one of the most critical factors determining the overall impact of climate change in the world. This is because a warmer atmosphere can hold more moisture that can be moved around by winds in the atmosphere, condensed to form clouds, and fall back to earth as rain or other forms of precipitation (IPCC, 2001).

Globally, the amount of water vapour in the atmosphere increases by 7% for every degree centigrade of warming (Trenberth, 2011). As a consequence, the total volume of global precipitation is likely to increase by 1-2% per every degree centigrade risen in temperature (Trenberth, 2011). Also, anthropogenically induced changes in atmospheric temperature is expected to increase the water holding capacity of air and thus make some regions of the world drier and other regions wetter (IPCC, 1996). This phenomenon is often referred to as the "*dry get drier and the wet get wetter*" phenomenon by climate scientists (IPCC, 2007). For example, there is evidence to show that land surface precipitation has increased over mid- to high-latitude regions of the world, notably over North America, Eurasia, and Argentina (IPCC, 1996). Conversely, increased evaporation can lead to surface drying and thus increase in the intensity and duration of drought in the world; such conditions are especially evident in the Mediterranean, southern Asia, and throughout Africa (IPCC, 1996). However, these effects are often difficult to distinguish from natural variability in the global climate. For example, El Nino generally makes wet regions wetter and dry regions drier. This report however, shows no difference between climate change and climate variability. Rather, the two terms are considered as describing one and the same phenomenon, i.e., any significant variation in the climate that can be attributed to natural or anthropogenic causes (Niasse, 2005).

Problem Statement and Justification

There is ample evidence that the global climate is changing, with a lot of uncertainties prevailing regarding the pace, the extent of change and the different impacts on nations in developing and developed countries. In Africa for instance, climate change is hardly a new source of threat. With climate change, the continent's vulnerability is deepening, making it the most exposed region in the world to the impacts of climate change (IPCC, 2014). Climate change projections for Africa in this century include a likely average temperature increase of 1.5 to 4^0C, which is higher than the reported global average of 0.5ºC (IPCC, 2014). Food and water security, livelihoods, shelter and health are all at risk. Widespread poverty, fragile ecosystems, weak institutions and the continent's unique geography compound these challenges. In this context, climate change has emerged as a key development issue for Africa. Man-made causes include widespread deforestation (IPCC, 2014). The resulting natural hazards are seen in both intermittent but increasingly frequent, extreme storm events and heat waves as well as impact on biodiversity through extinction of some life forms (Simon, 2007). Owing to these effects, climate change has become one of the greatest challenges of this century (IPCC, 2014). The threat of climate change is multidimensional and its impacts transcend national borders. Projections by the Intergovernmental

Panel on Climate Change (IPCC, 2007) indicate that if emissions continue to rise at their current pace, the world will be faced with serious consequences such as sea-level rise, shifts in farming seasons, biodiversity loss, as well as increased frequency and intensity of extreme weather; such as heat waves, storms, floods and droughts (IPCC,2007). It is perceived that developing countries, particularly the poor ones in Africa will be most affected, even though the largest share of historical and current global emissions of greenhouse gases originate in developed countries (IPCC, 2007).

Ghana is one of the countries in the West-African sub-region whose economy is highly dependent on climate sensitive sectors such as health, energy, agriculture, infrastructure, water resources, land, fisheries and forestry. Based on climate models, the Ghana EPA in 2008 determined that for every one meter rise in sea level, an area of about 1,100km^2 of coastal area will be inundated. This presents grave implications given that one-third of the Ghanaian population live within 3 km of the coast (IPCC, 2014). Climate variability in Ghana will therefore have adverse effects on coastal communities (National Climate Change Policy, 2012). Unfortunately, national activities do not give sufficient priority to climate change issues attributable to low institutional capacity to conceptualize integration of climate change issues in the country's developmental efforts (NCCP, 2012). Also, lack of financial and technical capacity to implement climate change related programs is an additional limiting factor. There are predictions of harder times ahead (IPCC, 2001). But the question is do coastal communities appreciate the changes in climate and what are their understanding of the causes, effects, mitigating strategies and efforts towards adaptation planning?

Purpose of the Study

The study will therefore investigate the ecological and social implications of climatic variability in a coastal community in the Western Region of Ghana with the view of recommending locally-relevant adaptation options. Akwidaa, a small fishing community in the Western Region of Ghana was used as a case study because of the perceived challenges of climate change impacts and efforts being made to adapt to these changes. The community therefore presents an ideal situation for this investigation.

Research Objectives

1. Evaluate changes in climate by analysis of anomaly trends for temperature, rainfall and relative humidity in the district from 1970-2012
2. Analyze the perception of the community on the causes and impacts of floods and drought on variables of climatic –induced risks
3. Assess the impacts of climatic variables such as floods and drought on fisheries and non-fisheries based livelihoods
4. document vulnerability of the community to drought
5. estimate adaptive capacity of the community to climatic variability based on relative index of Adaptive Capacity

Significance of the Study

The study is of high practical value because aside investigating the vulnerability context, i.e. the direct impacts on people and livelihoods; it will also address issues for adaptation planning in the chosen community. It will also present baseline information for comparison with similar situations along Ghana’s coast.

Delimitations

The study focused on both the Old town and New town of the Akwidaa community looking at the vulnerability of the community to climatic stressors. It only looked at vulnerability at the community level and not at the household and individual levels.

Limitations

Despite the success of the study, there were some challenges that the researcher faced during the study. The researcher encountered resentments from some community members as some members exhibited non-cooperative attitudes. Some community members felt it was a waste of time to grant interviews since previous studies conducted in their communities had not yielded any tangible results. Also, the interview method used for eliciting data from the communities posed a problem. There was difficulty in translating the questions into the local dialect of the respondents and recording respondents' answers which had to be translated from their local dialect into English. Therefore, there was the tendency of errors in asking questions and recording responses as they might not be as exactly as the original.

Organization of the study

Chapter one provides the introductory section, the background of the study, statement of the problem, the purpose and objectives of the study. The chapter also outlined the significance of the study, delimitation and the limitations anticipated. Chapter two looks at the review of literature pertinent to the study. Chapter three deals with the method used in collecting data, namely the research design, the study area, sampling method used and the research instrument applied. Chapter four analyses the results; impacts of assets and livelihoods to flood and drought, adaptive capacity estimation and the perception of respondents to changes in climate changes. Chapter five considers the summary of results, makes conclusions and provides recommendations.

CHAPTER TWO

LITERATURE REVIEW

This chapter presents review of literature on the Global climate and the changes climate.

Trends in global climate

The issue that the climate is changing is no longer subject to debate as several studies conducted by researchers all over the world confirm it. According to Hansen et al., (2001) global surface temperature increased in the past century by more than 0.5 ºC and NASA (2006) actually puts the warming over the past 100 years at 0.8° C. The U.S. National Academy of Sciences confirms that the last few decades of the 20th century were the warmest in the past 400 years (NASA, 2006). NASA scientists note 2005 as the warmest year since the late 1800s, 1998, 2002, 2003 and 2004 followed as the next four warmest years (NASA, 2006). These mean the five warmest years over the last century occurred in the last ten years. The 2005 atmospheric warming figures are very notable because until 2005, the 1998 warming was said to have been enhanced by the strongest El Nino of the century which added 2^{o} C warmth to global temperatures (Hansen et al., 2006) and some researchers had used that to counter the claims of global warming. Increase in global temperatures is in response to increasing emissions GHGs and they are consistent with expectations (IPCC, 2001). Land surface precipitation has also increased over the same period in the mid- to high latitudes, but shows a decrease in the tropics and subtropics (IPCC, 1996) and overall areas of the world affected either by drought or excessive wetness have increased. In Africa, atmospheric warming of 0.7°C over the 20th century has been observed which is a result of

0.05°C warming per decade through the 20th century as well as increased precipitation for East Africa (Hulme et al., 2001; IPCC, 2001)

Climate trends in West Africa

The climate trends of West Africa are similar to what has been reported globally with varying trends in temperature and precipitation. The climate of West Africa has a unique feature of being highly variable (Hulme, 2001). Varying from relatively stable humid areas with precipitation greater than 2000 mm per year, through the sub-humid and semiarid zones as one moves from the south into the Sahelian north renowned for having one of the highest levels of spatial and temporal climatic variability in the world (Wang, 2004). In the recent past, the West African region experienced unusually high rainfalls in the 1930s and 1950s and this was followed by severe drought from the 1960s to 1990s. This 30 year period of drought actually observed mean annual rainfall drop by as much as 30%, from 512 mm (1931- 1960 average) to 410mm (1971-2000 average) that culminated in the devastating Sahelian droughts of 1973, 1984 and 1990 (Hulme, 2001; Nicholson, 2001). In a study of rainfall during the period of 1998 to 2003 in some parts of West Africa covering most of Mali and Burkina Faso and the most northerly part of Ghana, Nicholson (2005) concluded that while still being below the wetter conditions that prevailed in the region from 1930 to 1965, the data revealed a clear recovery in rainfall compared to the 30 years climatological normal for the very dry period 1968–1997. The recovery was most marked in the western Sahel (Nicholson, 2005).

Climate trends in Ghana

The climate trend in Ghana has shown decreasing trends in rainfall with increasing temperature. One very recognizable feature of rainfall in Ghana is its seasonal character and very high year to year variability (IPCC, 2007). Rainfall in Ghana rarely prolongs for more than 3 hours in all parts of the country. In the dry months, rainfall duration would not reach 10 hours in a month and even in the wet seasons; the average total duration of rain is only about 30 to 40 hours in a month (EPA, 2000). Temperatures in Ghana are generally high, with little variation from year to year. Annual mean temperatures also show only small variations across the country. From 1961 to 1990, temperature rise of about 1 and reductions in rainfall of approximately 20% were recorded in Ghana (Ghana Initial National Communication to the UNFCCC; EPA, 2000). The analysis of national data on climate of Ghana (1960-2000) shows a progressive rise in temperature and decrease in mean annual rainfall in all agro-ecological zones (Guinea Savanna woodland, tropical rain forest, coastal scrub and grassland) in Ghana (Ghana National Climate Change Policy, 2012). The report shows that the average rate of increase in temperature has been 0.21°C per decade, with a more rapid increase in the northern regions of the country. Conservative estimates show increases of 1.7°C to 2.04°C by 2030 in the northern Savannah regions, with average temperatures rising as high as 41°C (GNCCP, 2012). This rise in temperature is greater than any change in atmospheric temperature in Ghana during the past 10,000 years (GNCCP, 2012). Historical climate data observed by the Ghana Meteorological Agency across the country between 1960 and 2000 (a forty year period), show a progressive and discernible rise in temperature and a concomitant decrease in rainfall in all agro-ecological zones of the country. Future climate change scenarios developed, based on the forty-year observed data, also indicate that temperature will continue to rise on average of about 0.6^{o}C, 2.0^{o}C and 3.9^{o}C by the year 2020, 2050 and 2080 respectively, in all agro ecological zones in Ghana. Scenarios of climate change development for the first National Communication (under the Country Studies Project) have shown sea level rise of 2.1 mm per year over the last 40 years in Ghana, with potential increases of 5.8 cm, 16.5 cm and 34.5 cm by 2020, 2050 and 2080, respectively. This will affect many communities within the 30 meter contour of the national coastal zone; where more than 25% of the population lives. Ghana's coastal zone is pivotal to the economy; with five large cities and significant physical infrastructure situated here. The coastal areas are already extremely vulnerable to flooding and erosion. Erosion, submergence and sea water intrusion will lead to the loss of economic, ecological, cultural and subsistence values through loss of land, infrastructure, and coastal habitats. Sea level rise and changes in freshwater inflows could impact on the habitats and biodiversity of coastal and marine ecosystems. Coastal and offshore gas, oil and electricity infrastructure is at risk of significant damage and increased shutdown periods from increased frequency of storm surges, flooding and high tide wave events. Already at the current sea level, the east coast of Ghana, (Keta area) is experiencing an annual coastal erosion rate of 3 meters (GNCCP, 2012).

Generally, rainfall in Ghana decreases from south to north. From the 40-year (1960-2000) dataset, rainfall levels have been generally reducing with the pattern of rains increasingly becoming erratic in all ecological zones in Ghana. The changing rainfall pattern has resulted in lower total precipitation per annum, with attendant of torrential rains and extreme events such as storms and floods. The erratic rainfall and its unpredictability are likely to jeopardize the employment of about 60% of the active population, majority of who are small scale rural farmers. Increased water stress will also reduce the availability of water for consumptive and non-consumptive uses. Rainfall is also predicted to decrease on average by 2.8%, 10.9% and 18.6% by 2020, 2050 and 2080 respectively in all agro-ecological zones of the country. (GNCCP, 2012)

Impacts of Climate Change

The projected changes in our climate are predicted to have adverse consequences for many regions in the world, impacting on key sectors such as water resources, agricultural, livelihoods, human health, infrastructure and settlements among others (Jodha, 1992). These impacts are discussed in the following sections.

Agriculture

Small-scale agriculture, primarily small-scale, is the backbone of Ghana’s economy (National Climate Change Policy, 2012). Agriculture contributes about 35% of Ghana’s GDP, generates about 30-40% of the foreign exchange earnings, and employs about 55% of the population (EPA, 2000). Despite its high contribution to the overall economy, this sector is challenged by many factors of which climate-related disasters like drought and floods mostly in northern Ghana is evident. The warmer atmospheric temperatures observed over the past decades are expected to lead to a more vigorous hydrological cycle, including more extreme rainfall events. Erosion is more likely to occur as a result (EPA, 2000).

Climate change is expected to have serious impacts on rural farmers whose livelihoods depend largely on rainfall. Due to the extremes of climate that would result, the increase in precipitations would probably result in greater risks of erosion, whilst at the same time providing soil with better hydration, according to the intensity of the rain. The possible evolution of the organic matter in the soil is a highly contested issue: while the increase in the temperature would induce a greater rate in the production of minerals, lessening the soil organic matter content, the atmospheric CO_2 concentration would tend to increase it. Sea levels are expected to get up to one meter higher by 2100, though this projection is disputed (EPA, 2000). A rise in the sea level would result in an agricultural land loss, in particular in low lying areas such as coastal areas. Increased sea level rise resulting in erosion, submergence of shorelines and salinity of the water table, could mainly affect agriculture through inundation of lands.

Climate change and variability would cause an increase in rainfall in some areas, which would lead to an increase of atmospheric humidity and wet season duration. Combined with higher temperatures, these could favour the development of diseases. Droughts and flooding will affect export earnings through crop and livestock losses, as well as causing widespread human suffering (Loladze, 2002). According to the IPCC's Third Assessment Report (TAR), "The importance of climate change impacts on grain and forage quality cannot be underestimated. For instance rice, the amylose content of the grain a major determinant of cooking quality is increased under elevated CO_2 (Conroy et al., 1994). Cooked rice grain from plants grown in high-CO_2 environments would be firmer than that from less CO_2 plants. However, concentrations of iron and zinc, which are important for human nutrition, would be lower (Seneweera and Conroy, 1997). Moreover, the protein content of the grain decreases under combined increases of temperature and CO_2 (Ziska et al., 1997; IPCC, 2001). Studies have shown that increases in CO_2 lead to decreased concentrations of micronutrients in crop plants (Loladze, 2002). This may have knock-on effects on other parts of ecosystems as herbivores will need to eat more food to gain the same amount of protein (Loladze, 2002). Studies have shown that higher CO_2 levels in the soil lead to reduced plant uptake of nitrogen (and a smaller number showing the same for trace elements such as zinc) resulting in crops with lower nutritional value (IPCC, 2014). This would primarily impact on populations in poorer countries less able to compensate by eating more food, more varied diets, or possibly taking supplements (IPCC, 2014). Reduced nitrogen content in grazing plants has also been shown to reduce animal productivity in sheep, which depend on microbes in their gut to digest plants, which in turn depend on nitrogen intake (Fisher et al. 2002). Increase in atmospheric greenhouse gas (GHG) concentrations is noted to be the single biggest factor in global temperature rise (Ladislaw et al., 2008) and CO_2 is the most significant greenhouse gas.

Human Health

Climate change is expected to increase the incidence of diseases in most parts of the world because the expected changes may create conducive environments for the growth and distribution of disease vectors (Arnell, 2006; WWF, 2006). The biological activity and geographic distribution of the malarial parasite and its vector, for example, are sensitive to climatic influences, especially temperature and precipitation (Martens et al., 1995;

Zhou et al. 2004). The spread of malaria is seasonal and limited to the warm and rainy months; however, changing climate conditions, such as the persistence of warm and rainy days for more of the year can increase the incidence of malaria events (Craig et al., 2004).

Among the factors that govern the distribution and population dynamics of malaria, Martens et al., (1995) stated that the abiotic are stronger than the biotic factors and rainfall and temperature are the most important of the possible abiotic influences. While other factors, such as topography and health preparedness can influence the spread of malaria, scientists have found a correlation between rainfall and unusually high maximum temperatures and the number of malaria cases (Githeko and Ndegwa, 2001; Zhou et al., 2004). Rainfall may influence malaria transmission by providing the medium for the aquatic stages of the mosquito life cycle, while temperature acts as a regulatory force (Martens et al., 1995). Rainfall may also increase the relative humidity and hence the longevity of the adult mosquito because between certain limits the longevity of a mosquito decreases with increasing temperature and increases with increasing relative humidity (Molineaux, 1988; Zhou et al., 2004 and Craig et al., 2004).

Additionally, the relationship between changing temperature, precipitation, and relative humidity are complicated and the processes affecting atmospheric humidity suggest only a small change in relative humidity as the atmosphere gets warmer (Mitchell and Ingram, 1992). Overall, human-induced climate change is expected to cause a change in the distribution and incidence of malaria (WHO, 1990; Doll, 1992; McMichael, 1993; Kai, 1994). Globally, a widespread increase of risk due to expansion of the areas suitable for malaria transmission and the predicted increase are most pronounced at the borders of endemic malaria areas (Martens et al., 1995) especially in Africa where it is common knowledge that malaria accounts for most of clinical cases and deaths, especially in children. An estimated 182 million people might die from disease associated with climate change by the end of the century in sub-Saharan Africa (IPCC, 2007), especially from malaria. In the highly endemic malarial areas of tropical Africa, the incidence of malaria and consequently the number of years of healthy life lost due to malaria may increase. In the malarial areas of lower endemicity, the incidence or infection is far more sensitive to climate changes (Martens et al., 1995). Meningitis is a lethal and greatly feared disease in affected areas, because of the rapid onset of symptoms and serious risk of mortality, as well as high rates of infection as many as 1 per 1,000 in parts of the African Sahel (Adamo et al., 2011). With mortality having more than doubled since the year 2000 and risks escalating as a result of climate change, mass inoculation is an attractive and life-saving component of any response to this growing challenge. The fact that meningococcal meningitis is largely a seasonal disease indicates the extent to which its prevalence is determined by weather-related parameters directly affected by climate change. Models that attempt to recreate meningitis epidemics show a high degree of success when calibrated with climate and environmental parameters. Meningitis epidemics are more likely to occur during the hottest, driest periods which are accompanied by high dust content in the air, and thus most likely to abate with the onset of the rainy season (Molesworth et al., 2003). The bacteria which causes meningitis is spread from person to person through coughing and sneezing, much like influenza or the common cold, and can be spread through poor sanitation (WHO, 2011). Bacteria can be present in a significant proportion of a population in areas affected by meningitis, but still remain benign. Dust is a key trigger, because it damages the tissues of the nose and throat, facilitating the passage of pathogenic meningitis bacteria into the bloodstream (Thomson et al., 2009). Climate change affects both weather (heat, humidity, wind) and the environment (extent of vegetation or desertification) and can increase heat, dust, and wind, resulting in exposure and creating peaks of meningitis (Thomson et al., 2011). Climate change intensifies those factors that most determine meningitis outbreaks, particularly humidity (drought) and dust levels for areas that will become more arid (WHO, 2011). Extreme high air temperatures contribute directly to deaths from cardiovascular and respiratory disease, particularly among elderly people.

High temperatures also raise the levels of ozone and other pollutants in the air that exacerbate cardiovascular and respiratory disease. Urban air pollution causes about 1.2 million deaths every year (IPCC, 2007). Pollen and other aeroallergen levels are also higher in extreme heat. These can trigger asthma, which affects around 300 million people. Floods are also increasing in frequency and intensity. Floods contaminate freshwater supplies, heighten the risk of water-borne diseases, and create breeding grounds for disease-carrying insects such as mosquitoes. They also cause drowning and physical injuries, damage homes and disrupt the supply of medical and health services. Rising temperatures and variable precipitation are likely to decrease the production of staple foods in many of the poorest regions by up to 50% by 2020 in some

African countries. This will increase the prevalence of malnutrition and under nutrition, which currently cause 3.5 million deaths every year (IPCC, 2007).

Recreation and tourism

Tourism is one of Africa's most promising and fastest-growing industries estimated to be about 15% per year based on wildlife and water supply for recreation. However, recurrent droughts in the past decade have depleted wildlife resources significantly (IPCC, 2007). Permanent loss of such attractions would waste vast amounts of investment in tourism. The greatest impacts would occur in drought-prone areas such as Africa. High levels of floral and faunal species diversity exist in various reserved areas in relict, fragmented patches of natural vegetation. Most wildlife is in reserved areas surrounded by human land use in the form of agriculture. This fragmentation and concentration of animals in specific areas make them highly vulnerable because vegetation (habitat) will not respond quickly enough to changed climate, and wildlife will be unable to migrate to more suitable climatic conditions because of limited corridors between wildlife reserves in different vegetation and climate types; moreover, wildlife would be slow in responding to a changing habitat boundary (Duke et al., 2007). Climate change will impact the tourism industry indirectly through changes in water and vegetation, as well as through wider-scale socioeconomic changes-for example, fuel prices and patterns of demand for specific activities or destinations. Various indirect impacts also may be derived from changes in landscape-the "capital" of tourism (Hulme, 1996) which might lead potential tourists to perceive Africa as less attractive and consequently to seek new locations elsewhere. There may also be new competition from other tourist locations as climate changes (particularly on seasonal time frames), in relation to northern vacation periods. Tourist attractions such as Victoria Falls could become much less attractive as a result of reduced river discharge and alteration of the rainforest. Hydrology models for tropical savanna Africa suggest reduced runoff as a result of climate change (Hulme, 1996). The tourist impacts of these changes will include alteration of characteristics of popular tourist destinations. In the 1992 drought period, Victoria Falls lost some of its attractiveness as a result of much reduced water discharge over the falls. Furthermore, the reduced flow resulted in reduction of the spray that maintains the rainforest that is part of Victoria Falls' aura-resulting in the death of flora around the falls. Changes in future climate should be actively considered in developing a sustainable industrial development path for Africa (IPCC, 2007).

Vulnerability in African tourism industry may relate more to the inhibiting effects of climate change on industrial expansion than to its effects on existing industrial installations and investments. The most serious impacts of climate change on this sector would be related to loss of competitiveness associated with increased costs of production resulting from changes or retrofitting of plants for cleaner production (Hulme, 1996). Reduced surface-water supplies would lead to extended use of groundwater sources-which, in most cases, have to be treated on site to achieve desired water-quality standards for specific industrial applications. Other major effects will result from a lack of water for industrial processes and increased costs of cooling for temperature-controlled processes and storage; Africa's industry has a large number of agro-industrial operations that need large amounts of water (UNEP, 2008). Besides these direct effects, there will be indirect effects, such as rising water costs; in cases of severe and recurrent water shortages, this factor could lead to relocation of industrial plants. Electricity shortages, due to a drop in the water level which causes a decline in hydropower, also will affect industry-particularly the steel sector (including iron and steel), ferro-chrome production, cement production, textiles, and aluminum production. These industries are among some of the most advanced on the continent, but they are highly dependent on constant electricity supplies. Although there are no data to indicate the level of water shortages that may result from a decline in precipitation, it is obvious that water shortages that affect concentrated urban settlements also will have a debilitating effect on industrial production. Water demand in many states in southern and northern Africa already has exceeded or is expected to exceed water supply soon.

Water resources

Among the various effects of climate change, increase in global mean temperature and changes in rainfall is likely to be the most hydrological important (Linhares, 2007). Complete disappearance of Kilimanjaro glaciers by 2015 – 2020 at current global warming rates has been projected by Thompson, Abreu and Wasielesky, (2002). The impacts of climate change on water resources are closely linked with changes in land cover and land use and have on some occasions been difficult to isolate. This is so because human-induced land cover and land use changes constitute a major source of anthropogenic influence that can independently cause both significant hydrological and climate changes through its direct effects on the hydrological cycle and greenhouse gas emission respectively. Reduction in water availability has been linked to thermocline circulation collapse and accelerated climate change. It must be noted that both thermohaline circulation collapse and accelerated climate change not only alter the annual volume of runoff, but in large regions change the timing of stream flow through the year – and this change in timing can have very significant impacts on resource availability and reliability (Arnell, 2006). In Africa, warm sea surface temperatures may lead to increased droughts in equatorial and subtropical Eastern Africa (Funk et al., 2005). Less precipitation during already dry months can lead to drought and increased desertification (IPCC, 2001). Some major rivers will be highly affected by climate reductions. From Arnell (2006), accelerated climate change increases the numbers of people with an increase in water resources stress by 2055 from around 1 billion to approximately 1.3 billion, with most of the increase occurring in Europe, North and Central America, and West Africa. Although the effects are not expected to be the same across the globe, accelerated climate change is expected to have relatively little effect on the numbers of people with an apparent decrease in water resources stress.

Fisheries and Aquaculture

Fish is highly nutritious, so even small quantities can improve people's diets (FAO, 2007). They can provide vital nutrients absent in typical starchy staples which dominate poor people's diets (FAO, 2005). Fish provides about 20 percent of animal protein intake (Thorpe et al., 2006) in 127 developing countries and this can reach 90 percent in Small Island Developing States (SIDS) or coastal areas (FAO, 2005). Although aquaculture has been contributing an increasingly significant proportion of fish over recent decades, approximately two-thirds of fish are still caught in capture fisheries. Fisheries can also contribute indirectly to food security by providing revenue for food-deficient countries to purchase food. Fish exports from low-income, food deficient countries is equivalent to 50 percent of the cost of their food imports (FAO, 2005). The number of people directly employed in fisheries and aquaculture is conservatively estimated at 43.5 million, of which over 90 percent are small-scale fishers (FAO, 2005). In addition to those directly employed in fishing, there are "forward linkages" to other economic activities generated by the supply of fish (trade, processing, transport, retail, etc.) and "backward linkages" to supporting activities (boat building, net making, engine manufacture and repair, supply of services to fishermen and fuel to fishing boats, etc.).

Taking into account these other activities, over 200 million people are thought to be dependent on small-scale fishing in developing countries, in addition to millions for whom fisheries provide a supplemental income (FAO, 2005). Some fishers are specialized and rely entirely on fisheries for their livelihood, while for many others, especially in inland fisheries and developing countries, fisheries form part of a diversified livelihood strategy (Allison and Ellis, 2001; Smith et al., 2005). Fisheries may serve as a "safety net" to landless poor or in the event of other livelihoods failing (FAO 2005). Marine and freshwater fisheries are susceptible to a wide range of climate change impacts. The ecological systems which support fisheries are already known to be sensitive to climate variability. For example, in 2007, the International Panel on Climate Change (IPCC) highlighted various risks to aquatic systems from climate change, including loss of coastal wetlands, coral bleaching and changes in the distribution and timing of fresh water flows, and acknowledged the uncertain effect of acidification of oceanic waters which is predicted to have profound impacts on marine ecosystems (Orr et al., 2005). Meanwhile, the human side of fisheries: fisher folk, fishing communities and related industries are concentrated in coastal or low lying zones which are increasingly at risk from sea level rise, extreme weather events and a wide range of human pressures (Nicholls et al., 2007). While poverty in fishing communities or other forms of marginalization reduces their ability to adapt and respond to change, increasingly globalized fish markets are creating new vulnerabilities to market disruptions which may result from climate change. A key feature of the socio-economics of inland fisheries, which may influence how they interact with climate change, is the intense seasonality of many highly productive floodplain fisheries. Somewhat related to this trend is the tendency for inland fisheries to be conducted by people who do not define themselves as fishers, but rather engage with seasonal fisheries alongside other livelihood options (Smith et al., 2005).

Human Settlements and Infrastructure

The pattern of distribution of human settlements often reflects the uneven nature of resource endowments and availability between regions and within individual communities (IPCC, 1996). In Africa, as elsewhere, there are heavy concentrations of human settlements within 60 km of coastal zones, in areas of high economic potential, in river and lake basins, in close proximity to major transportation routes, and in places that enjoy hospitable climatic regimes. Changes in climate conditions would have severe impacts not only on the pattern of distribution of human settlements but also on the quality of life in particular areas. For example, wetter coasts or drier conditions in up-country areas could lead to spontaneous migrations as an adaptive option.

Similarly, the pattern of energy use could change radically as a result of technological adaptations arising from climate change. IPCC (1996) and UNFCCC (1992) acknowledge that developing countries' energy demands must increase to meet their needs for economic development. This increase must occur so these countries can respond to their development needs and to support the needs of growing populations. More of this economic development will be in industrial and transport sectors than in any other sector. It has been argued that the growth of the energy, industry, and transport sectors is needed as countries go through their economic transitions, which will decrease their vulnerability. Current high dependence on land-based production activities-such as agriculture and fisheries-only increases the vulnerability of African countries.

The energy, industry, and transport sectors are thus important in discussing vulnerability and adaptation. The main challenges likely to face African populations will emanate from the effects of extreme events such as tropical storms, floods, landslides, wind, cold waves, droughts, and abnormal sea-level rises that are expected as a result of climate change. These events are likely to exacerbate management problems relating to pollution, sanitation, waste disposal, water supply, public health, infrastructure, and technologies of production (IPCC, 1996). Adaptation strategies lie mainly in relocating populations, efficient energy supply and use, introduction of adaptation technologies, and improved management systems. Because most of these strategies have high cost implications, existing economic constraints of

African countries may present major obstacles. In addition, implementing some of these strategies may have aspects that go beyond costs; relocation of human settlements from low-lying coastal areas that are vulnerable to inundation, for example, is likely to create problems that go beyond cost implications and include changes in social structure-clear policies on land use, fortified by flexible land-tenure regimes, will be needed.

Coastal Assets and Livelihoods

Coastal zones are amongst the most dynamic natural environments on earth, providing a range of goods and services that are essential to human social and economic well-being. Coastal zones represent the narrow transitional zone between the world's land and oceans, characterized by highly diverse ecosystems such as coral reefs, mangroves, beaches, dunes and wetlands. Many people have settled in coastal zones to take advantage of the range of opportunities for food production, transportation, recreation and other human activities provided here. A large part of the global human population now lives in coastal areas: estimates range from 20.6 per cent within 30 km of the sea to 37 per cent in the nearest 100 km to the coast (Nicholls and Small, 2002). At least 200 million people were estimated to live in the coastal flood plain (below the 1 in 1000 yrs. storm surge) in 1990 (Hoozemans et al., 1993). This is likely to increase to at least 600 million people by 2100 (6% of global population) as coastal populations are presently growing at twice the rate of global population increase (Hoozemans et al., 1993). Urbanization and the rapid growth of large coastal cities is another fundamental change (Nicholls, 1995). Collectively, this is placing growing demands on coastal resources and increasing exposure to coastal hazards such as erosion and flooding. Global climate change, particularly sea-level rise, will exacerbate all these ongoing problems and its potential implications are causing concern (Bijlsma et al., 1996). However, the impacts will vary from place to place depending on local and regional biogeophysical and socioeconomic factors. In addition, a considerable portion of global economic wealth is generated in coastal zones (Turner et al., 1996). Many coastal locations exhibit a growth in population and income higher than their national averages (WCC'93, 1994), as well as substantial urbanization (Nicholls, 1995a).

In the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), Bijlsma et al. (1996) noted that climate-related change in coastal zones represents potential additional stress on systems that are already under intense and growing pressure. The IPCC concluded that although the potential impacts of climate change by themselves may not always pose the greatest threat to natural coastal systems, in conjunction with other stresses they could become a serious issue for coastal societies, particularly in those places where the resilience of the coast has been reduced. This conclusion has been the main motivation behind the current proposed research, which has aimed at better understanding the vulnerability, resilience and adaptation of coastal zones in the face of climate change. In Ghana the EPA (2008) in collaboration with the Netherlands Climate Change Study Assistance Programme (NCCSAP) have conducted baseline surveys on climate change impacts on various sectors in the country "Ghana Climate Change Impacts, Vulnerability and Adaptation Assessment". The climate models have shown that for every 1 meter rise in sea level, an area of about 1,100km^2 of coastal area will be inundated. Given that about $^1/_3$ of the

Ghanaian population lives within 3 km of the coast, this situation presents serious challenges. There are additionally relevant data gaps that need to be filled as a basis for informed decisions for policy-making. These revolve around assessing the physical, organizational, social and economic (POSE) vulnerabilities of coastal communities to the impacts of climate change. The assessment of the vulnerability of Ghana's coastal zone to climate change carried out by the Environmental Protection Agency in 2000 provides a number of insightful results. It has been estimated that 3.3% of the population within the coastal zone is at risk as a result of inundation and shoreline recession and this population is mainly within the east coast. In the east coast, the erosion of the shores may be occurring at an average rate of 3 m per year. A total of 1,110 km^2 of land along the coast will be lost if nothing is done to protect them. Most of the affected areas are within the east coast. The areas east of the Volta River estuary are particularly vulnerable. The central coast is the least vulnerable in Ghana. The land at risk includes significant areas that are currently wetland with substantial amounts of mangroves. There will be rise in soil moisture content of sandy and silty soils along the coastal zone. These soils when subjected to vibrations will liquefy. The structures founded on these soils could thus be at risk of collapse during earthquakes. The rising water table as a result of sea-level rise will increase the risk of earthquake hazards.

The highest risk zone is the Accra area. The risk diminishes eastward and westward. The cost of protecting all shorelines at risk with populations greater than 10 persons per km2 with seawalls is US$1,144 million. The protection of important areas reduces that cost to US$590 million. Major water supply facilities that serve Axim, Sekondi- Takoradi, Cape Coast, Winneba and Accra as well as the South-eastern District Water Supply Scheme at Sogakope and Ada will be affected as a result of salt water intrusion, which has the potential of increasing water treatment costs. The EPA climate change vulnerability and adaptation assessment of the coastal zone of Ghana further revealed gaps in legislation and institutional arrangements for the management of the coastal zone.

Ecosystems and biodiversity

Mangrove forests are tropical intertidal habitats and are extensively developed on accretionary shorelines. Mangroves can provide important services for adjacent ecosystems, and also supply many useful products to human societies. For example, mangroves provide nursery habitats for many species of fish and invertebrates that spend their adult lives on coral reefs, sediment trapping to sustain offshore water quality for coral reefs, protection for inland sites from storm surges and flooding, building materials, traditional medicines, firewood and food (IUCN 1989). Mangroves also acts as carbon sink to reduce carbon dioxide concentration in the atmosphere. The impact of changes in climate may lead to loss or reduction in these resources and coastal inhabitants who are dependent on the resource may be affected and vulnerable to the changes in climate on mangroves. Mangrove species display a distinct zonation from low to high water, based on controls including the frequency of inundation and salinity exposure. This is controlled by the elevation of the substrate surface relative to mean sea level. Hence mangrove substrates can keep up with sea level rise through vertical accretion. Some of this accumulation will be from organic matter production, but this can be augmented by external inputs of sediment from rivers. Rates of accretion reveal that mangrove ecosystems are highly vulnerable to projected rates of sea level rise. Mangroves of low relief islands in carbonate settings that lack rivers are probably the most sensitive to sea level rise, owing to their sediment-poor environments and hence poor rates of vertical accretion (Ellison, 1993). Climate change can impact the dynamics of mangrove ecosystems through its effect on the level of the sea, ocean circulation patterns, precipitation, water and atmospheric temperature and CO_2 concentration. Of all these impacts sea-level rise- may be the greatest threat to mangroves (Field, 1995). It has led to a substantial reduction in the size mangrove ecosystems worldwide (Ellison 2000). This effect is predicted to increase, especially for mangroves under intense human exploitation, in the next decades in part due to the fact that a rise in the level of the sea exacerbates sediment erosion, inundation and increases the salinity mangrove water and sediments (Ellison 2000). Increased air temperatures and atmospheric CO_2 concentrations are also likely to increase mangrove productivity, change phonological patterns, and expand the ranges of mangrove forests into higher latitudes. Demands for timber (for charcoal, building etc.) and coastal development space have also been highly damaging. Mangrove forests in some areas have been reduced to mere relicts of their former ranges as a result of human exploitation. In addition to these pressures, mangroves are threatened by sea level rise, projected between 0.9 and 8.8 mm/year. Anticipated climate-related changes include: an accelerated rise in sea level of up to 0.6 m or more by 2100; a further rise in sea surface temperatures by up to 3°C; an intensification of tropical and extra-tropical cyclones; larger extreme waves and storm surges; altered precipitation/run-off; and ocean acidification. These phenomena will vary considerably at regional and local scales, but the impacts are virtually certain to be overwhelmingly negative. Corals are vulnerable to thermal stress and have low adaptive capacity. Increases in sea surface temperature of about 1 to 3°C are projected to result in more frequent coral bleaching events and widespread mortality, unless there is thermal adaptation or acclimatization by corals (Royal Society, 2005).

Coastal wetland ecosystems, such as salt marshes and mangroves, are especially threatened where they are sediment starved or constrained on their landward margin (Thorhaug et al., 1985). The ocean is also becoming more acidic (decreased seawater pH) as it absorbs atmospheric carbon dioxide (CO_2). Ocean acidification has potential widespread effects on marine ecosystems. It may inhibit calcification, which will threaten the survival of coral-reef ecosystems. It will inhibit the growth of calcareous algae at the base of the food web and of shell-forming marine organisms (such as scallops), and it will stunt the growth of calcified skeletons in many other marine organisms, including commercial fish species (Svensson et al., 2006). These species changes then affect local fisheries livelihoods and food supplies for coastal communities. Degradation of coastal ecosystems, especially wetlands and coral reefs, has serious implications for the well-being of societies dependent on the coastal ecosystems for goods and services. Increased flooding and the degradation of freshwater, fisheries and other resources could impact hundreds of millions of people, and socio-economic costs on coasts will escalate as a result of climate change (UNEP, 2006)

Energy

The impacts of climate change on the energy sector will be felt primarily through losses or changes in hydropower potential for electricity generation and the effects of increased runoff (and consequent siltation) on hydrogenation, as well as changes in the growth rates of trees used for fuel wood (IPCC, 1996). The total primary energy use in 1990 in sub-Saharan Africa (including South Africa) was broken down in the following shares: biomass fuels (53%), petroleum (26%), coal (14%), large-scale hydro (3%), natural gas (2%), and other renewable (2%). The most vulnerable areas of the energy sector to climate change in Africa are the provision of energy services for rural areas and, to some extent, for urban low-income needs. The extent of biomass dependence for the African energy sector is high; this dependence is critical because the source of biomass is supported only by the natural regeneration of indigenous natural forests (IPCC, 1996).

Ghana's Vulnerability to Climate Change and Variability

The current assessment of Ghana's vulnerability to climate change (Ghana EPA, 2000) concentrated on how changes in climate may affect some important sectors of the national economy which includes water resources, coastal resources and some agricultural crops. The assessments consisted essentially of analyzing the scope and severity of the potential effects of climate change, as a result of probable temperature rise, decreased precipitation and rise in sea level. Runoffs or discharges of all the river basins in Ghana are sensitive to changes in precipitation and temperature; a 10% change in precipitation or a 1oC rise in temperature can cause a reduction in runoff in excess of 10% (Ghana EPA, 2000). Projected climate change scenarios indicate reduction in river flows between 15-20% and 30-40% for the years 2020 and 2050 respectively in all the basins. Similar reductions in ground water recharges between 5% and 22% by the year 2020, and 30 and 40% were projected for 2050. This would result in serious constraints for water for irrigation; hydropower generation; secondary impacts on health, nutrition and energy-based industrial activities 40 (Ghana EPA, 2000).

The Ghana National Initial Communication to the UNFCCC concludes that by the year 2020 and 2050, all river basins will be marginally vulnerable and the country will face water management problems. Food production is also projected to decline. Using the projected climate scenarios and CERES model, it was projected that the yield of maize would decrease in the forest-savanna transition Zone from 0.5% in the year 2000 to 6.9% in the year 2020. The yield of millet however was not affected by the projected climate change because millet is more droughts tolerant and therefore insensitive to temperature rise. Ghana has moved from a Low Income to a Lower Middle Income country and is both high-growth and energy-hungry (National Climate Change Policy, 2012). However, it has been recognized that climate change and the cost of the climate change response is a serious threat to this progress. There is already evidence on the impact of climate change on the national economy, with clear signs that the coastal zone, agriculture and water resources are all affected, as well as poverty, health and livelihoods, especially for women. It is already affecting national economic outputs and livelihoods and, therefore, Ghana's long-term development prospects. The nation is particularly vulnerable to climate change and variability due to reliance on sectors that are sensitive to climate change, such as agriculture, forestry and energy production. Ghana's climate is already difficult to predict and the country can expect more intense weather events, such as torrential rains, excessive heat and severe dry winds as a result of climate change. Each weather event results in a setback to national development. The 2008 national sectoral climate change vulnerability and adaptation assessments revealed the substantial impact of climate change on the national economy. Flooding, for example is an obvious and immediate threat to economic growth, energy supply, roads and transport, food and agriculture, education, health, water and sanitation and social protection.

The National Disaster Management Organization (NADMO) responds to flooding disasters every year. The June 2010 floods demonstrated how climate change can reverse development investments, with a total of 24 deaths, more than a 1,000 homes destroyed, millions of dollars in property losses, 5,000 people evacuated in Tema and a bridge linking Ghana and neighboring Togo collapsed, cutting off travel between the two West African countries. The shortening of the growing season also has severe impact on food security in areas which practice rain fed agriculture. Lower agricultural productivity from extended dry seasons and flooding from storm events are also increasing the pressure on the young and mobile in the north to migrate to the South. Migrants arriving in the cities, many of them young women who make a precarious living as porters (*kayayei*), are exposed to new vulnerabilities on the streets and add to the pressure on existing over-stretched urban services.

Adaptive Capacity to Climate Change

The challenges we all must face in adapting to climate variability and change present themselves with increasing urgency. Nowhere will these challenges be greater than in the developing world where often weak institutions and governance systems struggle to deal with mounting pressures from population growth, inadequate infrastructure, and diminishing or already depleted natural resources. The reason for the shortage of adaptive capacity is the lack of scientific, technical, financial and institutional capacity to evaluate the impact of climate change. These very constraining factors also make it difficult to implement adaptation measures. Adaptation to climate change is one of the critical issues in climate studies because from all Indications, climate change is real and living with it requires planned activities that will reduce its effects and make life possible. The great need for adaptation is given attention in Article 4.1.b of the United Nations Framework Convention on Climate Change (UNFCCC) which provides that all countries must formulate and implement national or regional programmes containing measures to facilitate adequate adaptation to climate change (Art. 4.1. b). Adaptation to climate stimuli includes adaptive responses to extremes, variability from year to year, and to changes in long-term mean conditions, both independently and as they relate to each other (Smit et al., 2000). Adaptation to climate change has been given several definitions and at different times have meant differently from author to author and this, according to Smit et al., (2000), requires a need for users of the term to specify adaptation in what, and to what. There are several definitions of Adaptation to climate change (Burton, 1992; Smit, 1993; Stakhiv, 1993; Smith et al., 1996 and Watson et al., 1996) but they all refer to adjustments in a system in response to climatic change, or/and variability.

The IPCC defines Adaptation to Climate Change ‘as a process by which strategies to moderate, cope with and take advantage of the consequences of climate events are developed and implemented (IPCC, 2001). According to Easterling (1996) adaptation can be either autonomous (reaction of individuals to changing climate) or planned (conscious policy options or response strategies) Similarly, Smit (2000) group's adaptations into passive, reactive or anticipatory; and spontaneous or planned. Stakhiv (1993) groups adaptive strategies according to the time frame of the stimulus: long range, tactical, contingency, and/or analytical and Smithers and Smit (1997) differentiate adaptations on the basis of intent or purposefulness, the role of government, the spatial and social scale, duration, form and effect. Climate change effects are not for a single group of people, although they are expected to be higher in tropical regions (Thomas and Twyman, 2006). However, the need and extent of adaptation varies within and between locations. Climate change and variability are among the most important challenges of Least Developed or developing countries because of their strong economic reliance on natural resources and rain-fed agriculture (FAO, 2007). Of the developing countries, many in Africa are seen as being most vulnerable to climate variability and change (Slingo et al., 2005). Observational records show that Africa has been warming through the 20th century at the rate of between 0.26 and 0.50^{o}C per century, and there is evidence that this warming trend will significantly accelerate in Africa (IPCC, 2007).

According to the IPCC Fourth Assessment Report (2007) a medium-high emission scenario would see annual mean surface air temperatures expected to increase between 3^{o}C and 4^{o}C by 2080 (IPCC, 2007). Moreover, most of Africa, particularly sub Saharan Africa, relies on rain-fed agriculture and as a result it is very vulnerable to changes in climate variability, seasonal shifts, and precipitation patterns. This high vulnerability of Africa to climate change requires the formulation of effective adaptation strategies but this is hindered by lack of resources. In effect, resource-poor communities who depend mostly on natural resources for their livelihoods, such as peasant crop farmers in Africa, are particularly critical when it comes to formulating adaptation strategies but they also have the lowest capacity to adapt (Thomas and Twyman 2006). FAO (2007) makes it clear these countries with limited economic resources and insufficient access to technology will be least able to keep up with the changes.

CHAPTER THREE

RESEARCH METHODS

Introduction

This chapter explains the research methods employed, namely the research design, the population and the study sample, the sampling method used, research instrument, data collection procedure and data analysis.

Research Design

The research made use of descriptive survey design. A descriptive survey design is one in which information is collected without changing the environment. It usually the best methods for collecting information that will demonstrate relationships and describe things the way it is This type of is often done before an experiment, to know what specific thing to include in an experiment. Bickman and Rog (1998) suggest that descriptive studies can answer questions such as "what is" or "what was".

The descriptive survey design is versatile and practical and is directed towards the determination of situation and also determine the distribution and interrelations among sociological and psychological variables and indicates how data collected, organized and displayed in tables and graph. It also helps to identify and define problems, select tools for collecting data, describe, analyses and interpret the data in clear and precise terms. Despite the advantages assigned to the descriptive design, care will be taken to ensure that questions to be responded to are clear and not misleading because the result of the survey can vary depending on the wording used.

The Study Area

This study was conducted in Akwidaa a coastal community (latitude 4° 45' 0 N and longitude 2° 1' 0 W) in the Ahanta West District of the Western Region of Ghana. This community was selected because of its location on a tiny strip of land as part of a sandy peninsular in the 30m contour part of Ghana. The community is divided by a lagoon into two suburbs, i.e., ‘Old Town’ and ‘New Town’. The community experiences a bimodal rainfall pattern: a main season from May to August and a minor season from September to October according to the Ahanta West District Assembly. Temperature throughout the district is generally high with a mean annual temperature above 26ºC.

Population

The target population for this study involved all fisherman, fish processors and traders, youth, farmers, elders, district assembly officials and traders in the community. Presently, the total population of the community is about 1500.

Sampling Procedure

A sample is a representative subset of a population which has all the important characteristics of the population from which it is drawn. Sample size and the technique used are influenced by the availability of resources in particular financial support and time available to select the sample (Saunders et al, 1997). Sampling techniques provide a range of methods that enable the researcher to reduce the amount of data you need to collect by considering only data from a sub-group rather than all possible cases. Many researchers, such as Moser and Kalton (1986) and Henry (1990) argue that using sampling enables a higher overall accuracy than does a census. The smaller number of cases for which you need to collect data means that more time can be spent designing and piloting the means of collecting these data. Collecting data from fewer cases also means that you can collect more detailed information. In all 220 respondents were used in the study. The 220 respondents were selected for the study using the simple random sampling. Simple random sampling involves the selection of the sample at random from the sampling frame using either random number tables or computer. In this context, the random number tables were used. First each of the respondents were given a unique number beginning from 0, then I and so on. Then cases were selected using random tables. The first random number was chosen by closing the eyes and pointing with the finger. Starting with this number the sample size was obtained by reading off the random numbers in a regular and systematic manner. No number was read off a second time. This form of sample is often used when you wish to select cases that are particularly informative (Neuman, 1991). The researcher found it appropriate to use purposive sampling in selecting the district official because it was considered necessary to involve all heads of the departments of the district assembly. Neuman (1991) looks at purposive sampling as one that enables the researcher to use his judgment to select cases which will best enable him to answer research questions and meet his objectives. Neuman further considers purposive sampling as the type that is often used when working with small samples such as case study research and also when the researcher wishes to select cases that are particularly informative. The logic on which you base your strategy for selecting cases for a purposive sample should be dependent on your research questions and objectives.

Data Collection Instrument

Data collection consisted of a range of data acquisition methods namely pilot studies, interviews using semi-structured questionnaires (Appendix B) and resource mapping technique. Climate data was also collected form the Ghana Meteorological Agency for the analysis.

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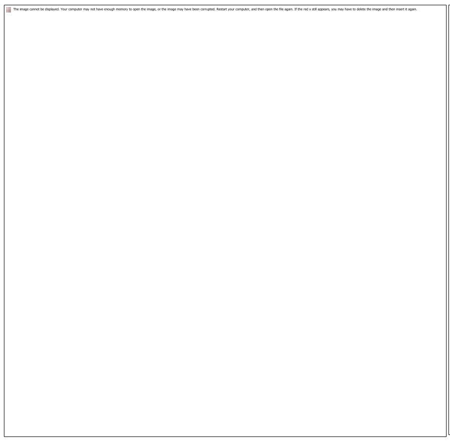
Data Collection Procedure

The data collection involved the administering of questionnaire to collect information on respondent's demographic status such as gender, age, qualification, impacts of climate stressors and adaptive capacity to these stressors. .

Pilot Studies

Prior to the main research, a pilot study was conducted in the community within the context of a "Climate Change Resilience Project" of the Coastal Resource Centre- Ghana that sought to enhance capacities of district officials and community leaders to incorporate coastal vulnerability assessment into the district planning processes. A pilot study is a feasibility study designed to test or review information or situation prior to a main study in order to improve the latter's quality and efficiency. A pilot study reveals deficiencies in the design of a proposed study or procedure to allow for the identified deficiencies to be addressed before time and resources are expended on large scale studies.

The overall goal was to develop a draft model process that could feed into local plans of the Assembly for coastal management and adaptation planning to climate change. The pilot study was aimed at informing the study of relevant knowledge gaps that could be addressed by the main study. The study therefore enabled the identification of pertinent issues prevailing in the community including existing assets, livelihoods, governance systems, climate and non-climatic factors and adaptive Strategies existing in the community. This information was obtained through interview sessions and participatory mapping approach.



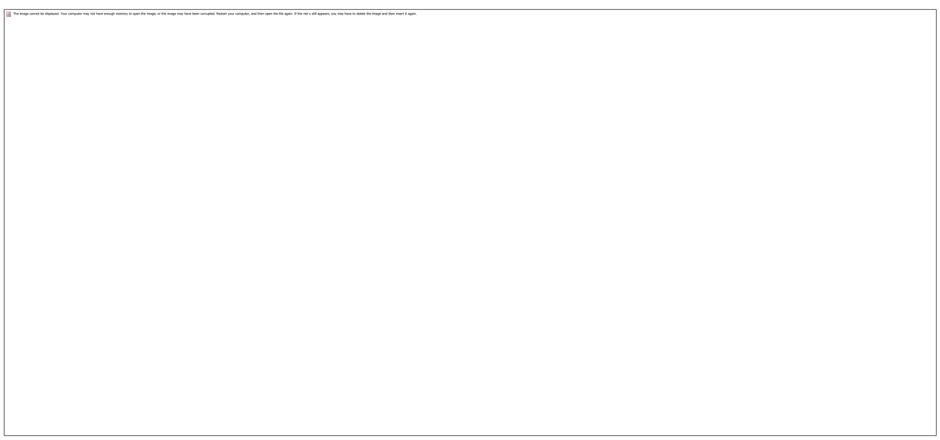


PLATE I: Some field activities in Akwidaa during pilot studies

Semi-Structured Interviews using questionnaires (Appendix A and B)

A semi-structured interview is a qualitative method of inquiry that combines a pre-determined set of open questions that prompt a discussion with the opportunity for the interviewer to explore particular themes or responses further. This method was used in the research to answer questions on the vulnerability of the community to climate induced hazards through interviews with the district assembly officials and community members. The justification was that, these respondents had been in the community for a long period of time and had better knowledge of changes in the climate, the causes, impacts and adaptive capacity of the community.

Interviews with District Assembly Officials using questionnaire (Appendix A)

A set of open ended questions were used to assess the vulnerability context of the community by asking district assembly officials about adaptive measures employed by both the district and community against the climate induced risks. The district officials included heads of the National Disaster Management Organization (NADMO), Environmental Health Department, Town and Country Planning and the Social and Community Development Department of the Ahanta West District Assembly. Information on the vulnerability and especially available adaptive capabilities at the district level and in the community against the climate induced risk was obtained from these officials. This was done through interview sections with the various heads of department using a questionnaire since they have much information on the issue.

Interviews with community members using questionnaires

In order to identify impacts of climate variability on the livelihoods and items of economic value within the study area, a set of specific questions (Appendix B) were devised for the members of the community to answer; the questions were devised based on the general approach for developing questionnaires for semi-structured interviews. Primary data on impact, vulnerability and coping strategies were collected using household interviews from May to July, 2013. The interview questions focused on a range of issues including socioeconomic status (sex, gender, sources of livelihood and age), climate change impact on the livelihood and assets, coping mechanisms, exposure and factors exacerbating vulnerability. A purposive sampling was used to select individuals from the Old town where they were grouped into smaller clusters to be interviewed. These included chiefs, elders, fishermen, fish traders, youth and farmers. A total of 220 respondents were interviewed using questionnaire. The assumption was that the respondents had enough knowledge of the changes that have occurred in the community over the years. Each interview lasted about 25 to 40 minutes. The questionnaire aimed to identify current observed climate variability and impacts of such changes on the livelihoods and assets of the community. The questionnaire sought the views of individual community members in order to avoid influence by others when done in a group.

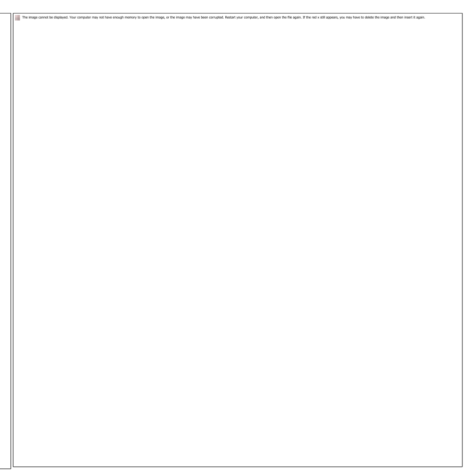


PLATE II: Interview sessions in community with elders and fisher folks

Participatory resource mapping

Participatory mapping, also called community based mapping, is a research technique that combines modern cartography with participatory methods to generate spatial representation of knowledge within local communities (Chambers, 1999). It is based on the premise that local inhabitants possess sufficient knowledge of their local environment which can be expressed in a geographical framework for easy understanding and universal recognition. The approach was employed to identify the location of available resources in the area with on a map by the locals. Furthermore, the approach was used to visualize existing social infrastructure, land use patterns, and location of social and natural resources (e.g., fisheries) in the community. As part of this interviewing technique, members of the community were made to sketch a map showing the location and boundaries of their resources both on land and at sea. To start the activity, members were asked to put boundaries to their community and also show their neighboring communities, as well as their offshore fishing areas at sea. This was then followed by the location of various resources on the map in order to determine the changes that have taken place over the years- and identify locations were these resource could be found in the community. Some examples of the resources located on the map included schools, roads, bridges, hospitals, churches, lagoon, sea, settlements and water resources.

PLATE III: Identification of assets and resources available by locals on a map

Data Processing and Analysis

Evaluation of climate data

This aspect presents the analysis of data on temperature, relative humidity and rainfall in the district using historical climate records from the Ghana Meteorological Agency (1970-2012) to elucidate the past and current trends. The data were analyzed by using linear regression analysis and descriptive statistics to determine;

(ι) Historical trends in climate conditions (ιι) Percentage increase, decrease and rate of change of the temperature and rainfall

(ιιι) Mean values recorded for rainfall, air temperature and relative humidity.

Anomalies of climate data

In order to determine long term changes in climatic conditions in the study area, the anomalies, i.e., departure from a reference value, associated with temperature, rainfall and relative humidity data were calculated according to Jones et al. (2008).

Drought

In the study, the level/intensity of dry conditions in the study area was determined based on the differences between the amount of rainfall and the rate of evaporation .Where D- dry conditions, R- rainfall and E- rate of evaporation

$D = R - E$

The rate of evaporation was computed using equation adapted from Jones et al., (2008):

$$Rate\ of\ Evaporation\ (E) = (\Theta)(Hs - h) mm/h \quad (1)$$

where, Θ= (25+19v) is the evaporation co-efficient, v= velocity of air (m^2h), Hs= Maximum humidity in air (mm) and h= humidity ratio in air (mm)

Flood

In the study, the level of flood was determined based on the sum of the rate of evaporation and amount of rainfall.

Theoretical Framework

A conceptual framework for climate change vulnerability assessment is presented in Figure 1 according to Allison et al., (2009). The model assesses vulnerability based on exposure to climate change, sensitivity and adaptive capacity. This model was employed in this research to assess and obtain information on the vulnerability and adaptive capacity of the Akwidaa community to climate induced hazards through interviews, analysis of climate data, assumptions and resource mapping approach.

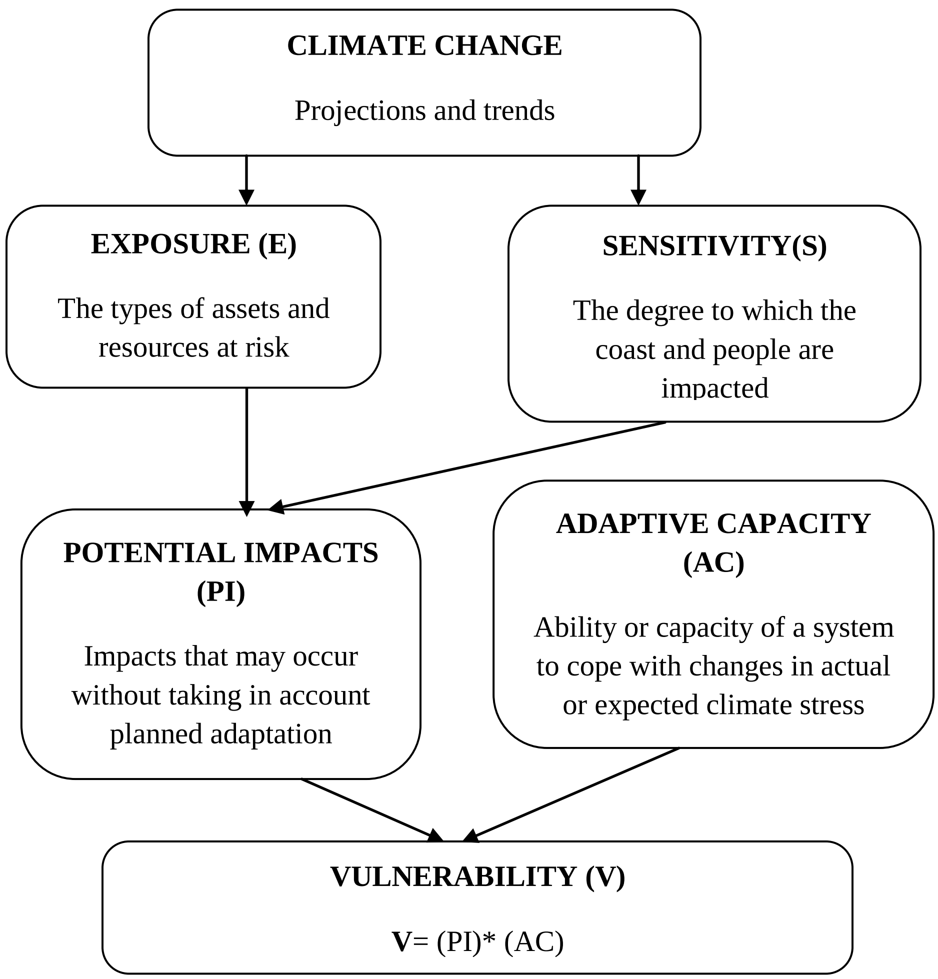


Figure 1: Theoretical Framework for Vulnerability (Source: Adapted from Allison et al., (2009b)

Analysis of Exposure, Sensitivity and Adaptive Capacity using Assumptions

To determine the sensitivity, exposure and the adaptive capacity of the community assets and livelihoods to drought, certain assumptions were made based on data collected during the study and information by literature in order to obtain the vulnerability of the community to the climate induced risk.

Exposure

Exposure is the contact between a system or system component and a perturbation or stress. It is a function of both the magnitude and scope of the perturbation, and the system which it influence (Kasperson et al., 2002). The exposure was computed by weighing the current dry conditions for each year against the long term mean of forty three years to know how exposed the assets and livelihoods are to drought and flood. The exposure therefore was computed as;

$$Exposure\ (E) = \frac{Current\ dry\ conditions\ or\ rainfall\ level}{Long\ term\ mean} \quad (2)$$

Sensitivity

The degree to which a system is affected or impacted, either adversely or beneficially by climate induced risk (IPCC, 2001). In this regard, resources available in the community that make the community less sensitive to drought and flood were weighted against some best adaptive capacities recommended based on some observations during the study to determine the sensitivity of the community to the climate induced risk. The assumption was that, if the appropriate adaptive measures are available in the community, the community would be less or not sensitive to the impact of drought. A score range of 0-1 was awarded to both the resources available in the community and that of the best practices to determine how sensitive the community is to this climatic induced risk. A score of zero implies the community is not sensitive to the impact of flood and drought or the community meets standards recommended in literature. A score of 0.5 implies there are some resources available in the community but are not enough to cope well with the impact and a score of 1 is indicative that the community is largely sensitive to drought. The sensitivity therefore was calculated as:

$$Sensitivity = \frac{I}{J} \tag{3}$$

Where, I= Total score of the resources available in the community and J= Total scores of the best practices adaptive capacity to make them not sensitive

Adaptive Capacity

Ability of a system to adjust to climate change (including variability and extremes) to moderate potential damages, take advantage of opportunities, or cope with the consequences (IPCC, 2001). In determining the adaptive capacity of the assets and livelihoods to drought and flood, the approach employed in assessing the sensitive was used. However, scores were awarded based on the adaptive techniques of the people in the community against some best adaptive practices in literature to enhance the adaptive capacity by the community. A score range of 1-0 was employed here; where a score of 1 implies that the adaptive capacity of the community is high based on the some best practices in literature making them not vulnerable to drought and flood. A score of 0.5

implies that the community is putting in some efforts to adapt better and a score of 0 indicative that the adaptive capacity of the community is weak making the community vulnerable to drought. The adaptive capacity was therefore calculated as the ratio:

$$Adaptive\ Capacity\ (AC) = \frac{X}{Y} \qquad (4)$$

Where, X= Total Adaptive Capacity of the community to drought and flood

Y= Total best adaptive practices in literature to make the community not vulnerable to the climate induced risk. Based on these equations the exposure, sensitivity and the adaptive capacity of the community was calculated to know how vulnerable the community is to drought.

RESULTS

Climate Trends in the Ahanta West District

Temperature Variations

Changes in air temperatures in the Ahanta West District generally reflect warming over the period under study. Analysis of mean air temperatures showed that maximum air temperatures rose by 6.4% over the period from 1970-2012. From an average temperature of 28.97°C in the first decade, 1970 – 1979, the average temperature for 1979 to 2012 increased to 29.52 °C, about 0.55 ^{o} C or 1.8% rise temperature. The temperature records therefore show a gradual increasing trend of about 0.02ºC over the last four decades (Figure. 3).

Figure 4 shows the trend in temperature anomaly which shows a clear variation over the 43year period. The long term mean temperature was 29.5ºC. The negative anomaly observed indicates colder years in temperature between 1970- 1980 and the postive anomaly indicates warmer temperature within the period 1980-2012.

Figure 3: Mean Annual Temperature of the Ahanta West District (1970-2012)

Figure 4: Temperature Anomaly Trend of the Ahanta West District (1970-2012

Rainfall Variations

Figure 5 shows the rainfall trend of the study area. The least annual rainfall of 100.0 mm was recorded in 1983 and 1998 whilst the highest annual rainfall of 245.9 mm was recorded in 1979. Mean annual rainfall has generally decreased by 145.9 mm from 1970 to 2012.

Figure 6 shows the rainfall anomaly trend. The positive anomaly indicates increase in rainfall and the negative anomaly shows a decrease in rainfall. Rainfall has generally decreased by 20 mm from 1980-2012.

Figure 5: Mean annual rainfall of the Ahanta West District (1970-2012)

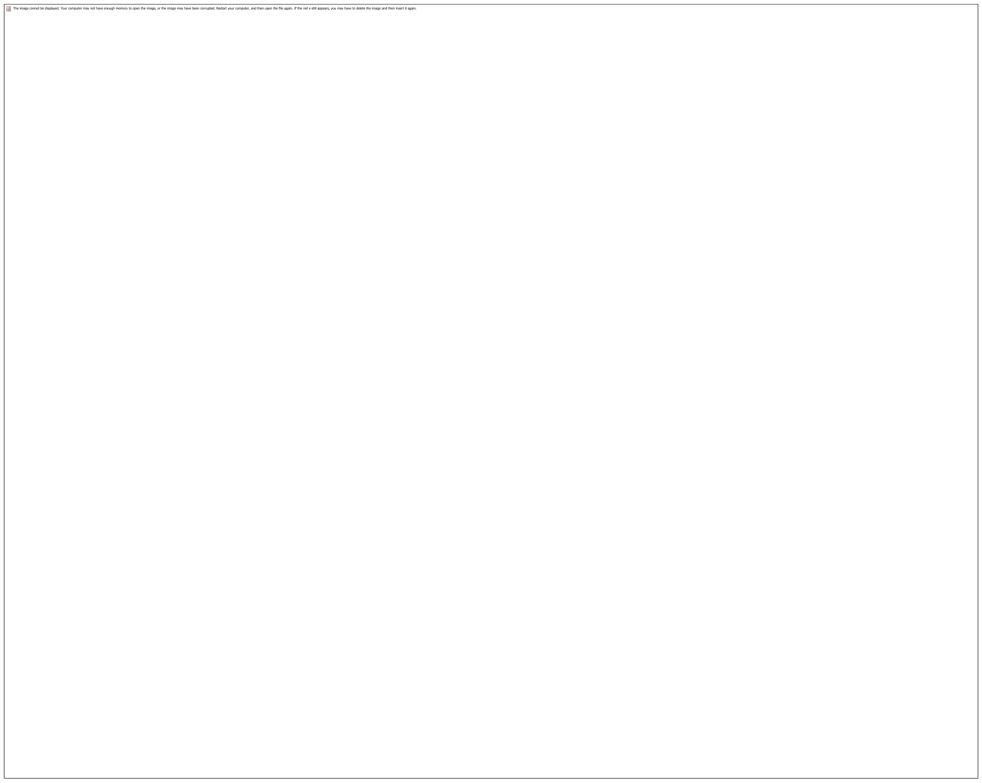


Figure 6: Rainfall anomaly trend from 1970-2012

Analysis of Temperature and Rainfall over 43 years

Between 1970 and 2012, mean temperature trends have generally increased whilst rainfall trends have shown a gradual decline (Fig. 7). There is a negative correlation between annual temperature and rainfall (Fig. 8). The analysis indicates that for any given year, as temperature increased, there is the probability that rainfall will decrease. The relationship between temperature (T) and rainfall (R) was describe by the equation T=-0.004R+27.253 with a co-efficient of determination (R^2) of 0.125.The negative correlation between temperature and rainfall is evident in the decadal analysis (Figure. 8).

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Figure 7: Mean temperature and rainfall in the Ahanta West District

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Figure 8: Correlation between temperature and rainfall of the Ahanta West District over a period of four decades

Changes in humidity

Figure 9, shows the variation in relative humidity over the period assessed. However, the mean annual relative humidity recorded for the district shows a gradual decline over the period assessed. Mean relative humidity was higher in the first decade reduced in the first two decades (from 1970 to 1980), when values ranged from 79mm to 79.5mm but it declined to 72mm from 1982 to 1998. It was slightly higher from 1999 to 2006. There was a marginal decrease from 2006 to 2012. Relative humidity has generally decreased by 0.05mm over the four decades.

Figure 10 shows the anomaly trend of relative humidity. The trend shows higher humidity in first decade and declined from 1980 to 2000. It decreased gradually from 2000 to 2012 estimated at 2mm over the period.

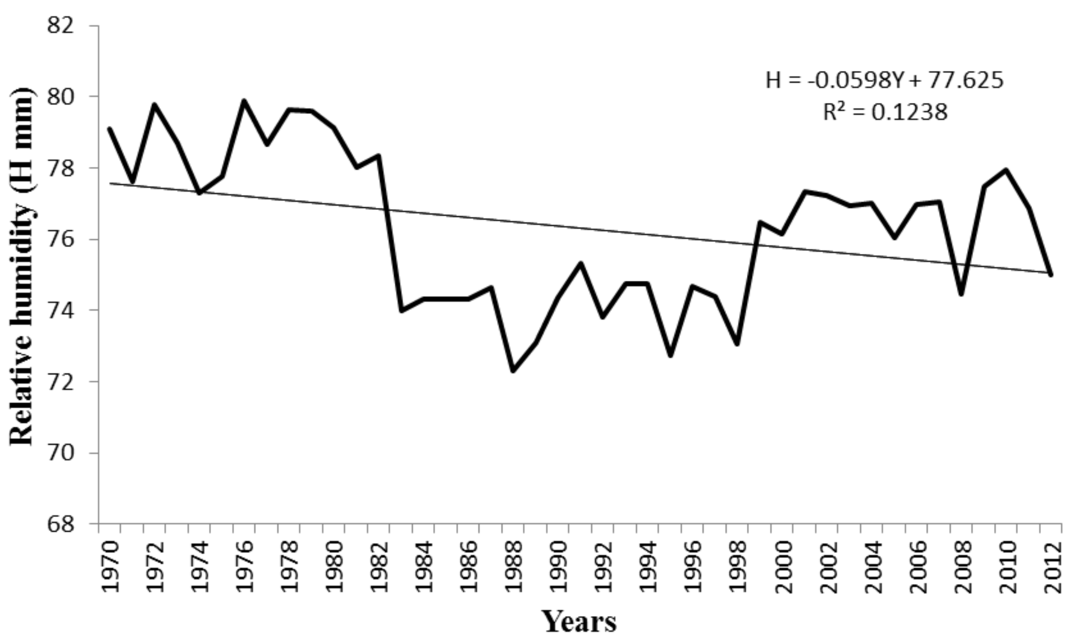

Figure 9: Mean annual relative humidity in the Ahanta West District

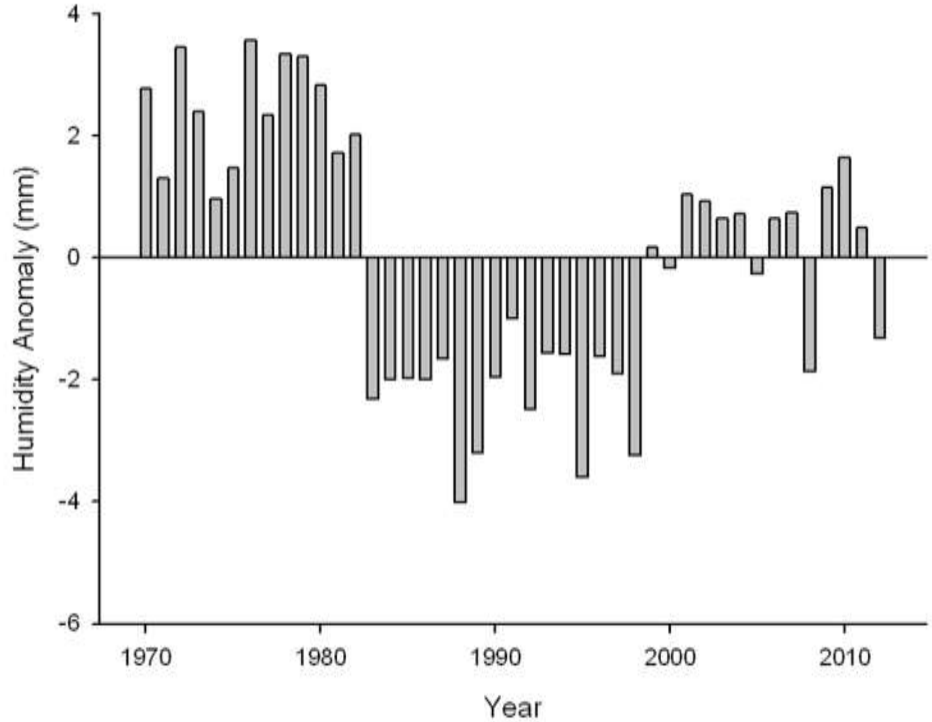

Figure 10: Anomaly Relative Humidity in the Ahanta West District

Changes in the rate of evaporation in the Ahanta West District

Figure 11 shows changes in the rate of evaporation over the period assessed. The rate was generally low from 1970 to about 1982. Evaporation rate was higher thereafter until 1995, reducing slightly from 1996 to 2005. The trend is seen to increase gradually for the rest of the period of observation increased steadily from 2005 through to 2012. The trend generally shows an increase in rate of evaporation.

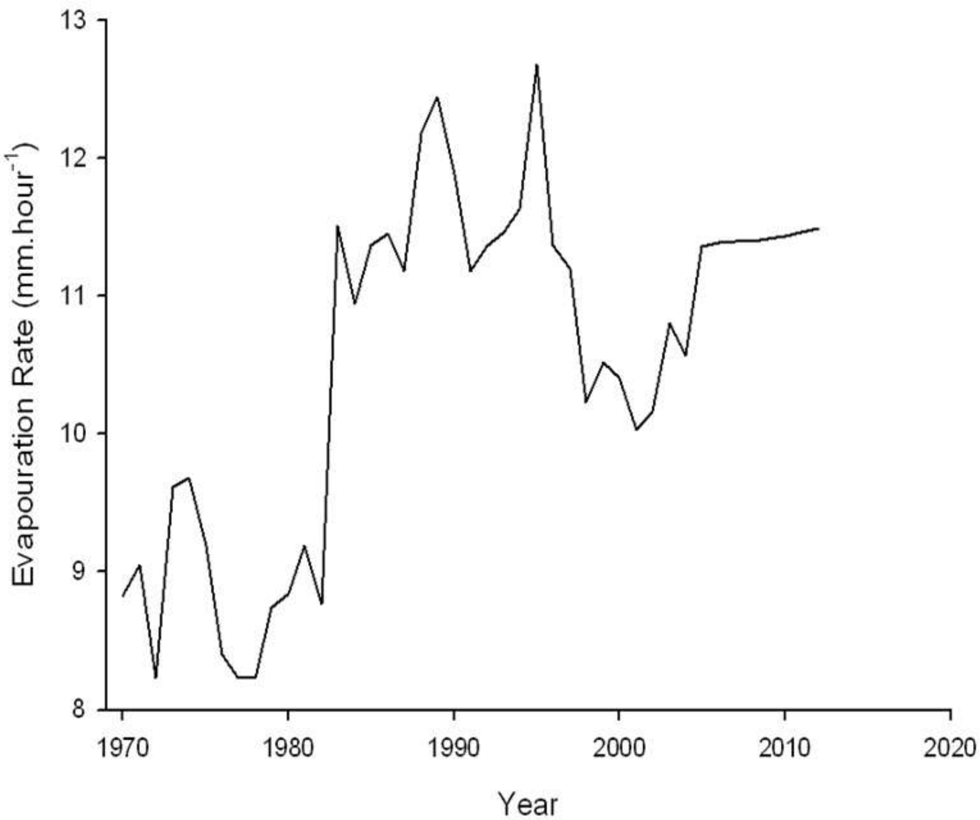

Figure 11: Rate of Evaporation in the Ahanta West District

Drought trend in the district

Figure 12, shows the trend of drought in the community of the last four decades. The trend shows a rapid increase from 1970 to 1983 and slows down to 1995. The trend increased gradually from 1996 to 2012.

A similar trend is seen in the exposure of the community to drought. The trend shows an increase in exposure over the period assessed (Figure.13)

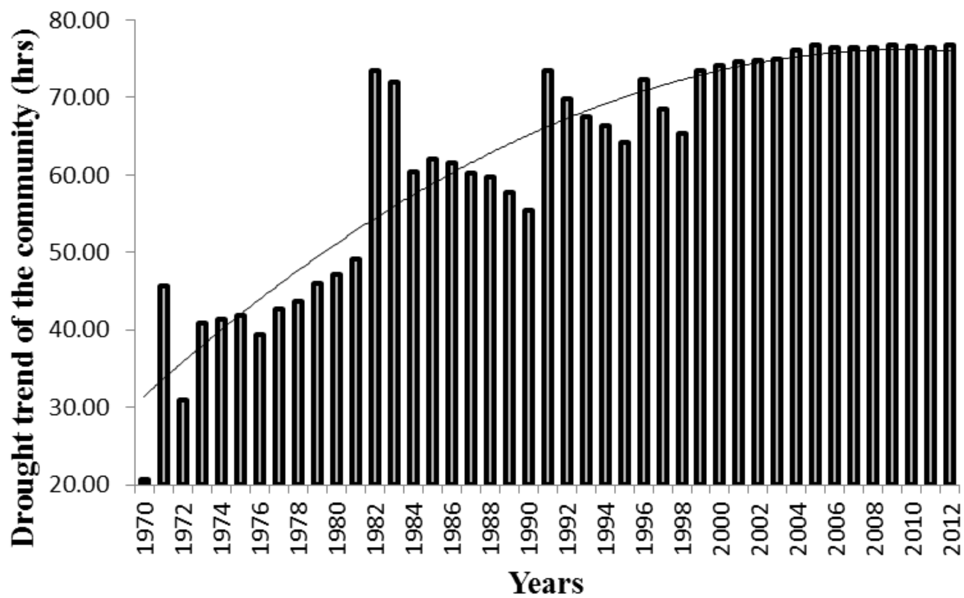

Figure 12: Trends of drought condition in Akwidaa from 1970-2012

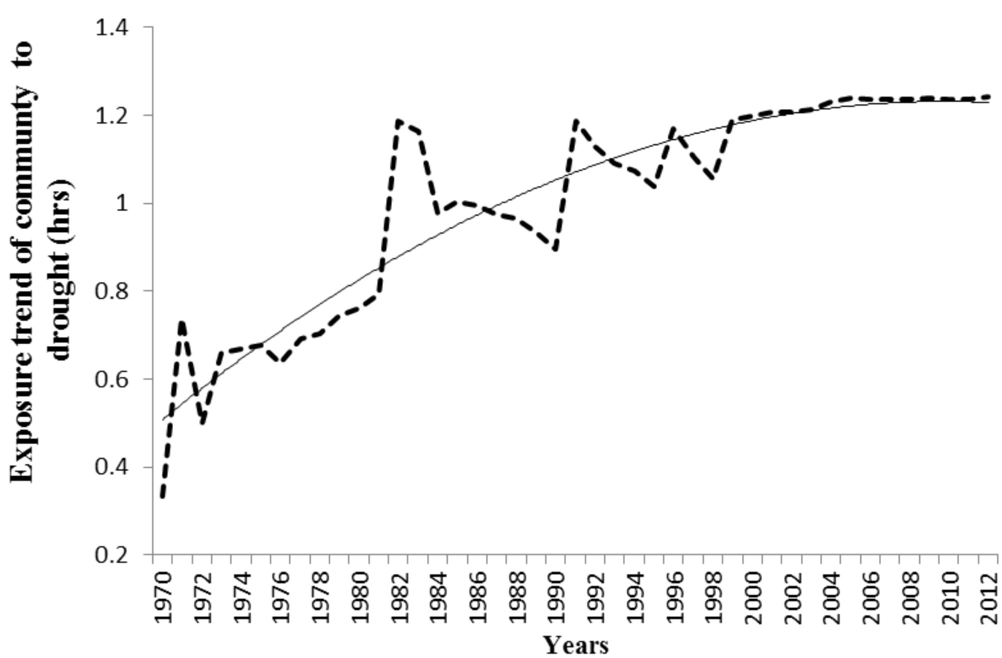

Figure 13: Exposure of Akwidaa to drought from 1970-2012

Perception of Community about Changes and Causes of Climate Variability

Figure 14 shows the perception of respondents on the changes in climate of the study area. Response from the members of the community indicated that, there have been changes in climatic phenomena over the years. 95% to 85% of the respondents strongly agreed that there has been a long-term change in climate. 19% agreed while 5% disagreed.

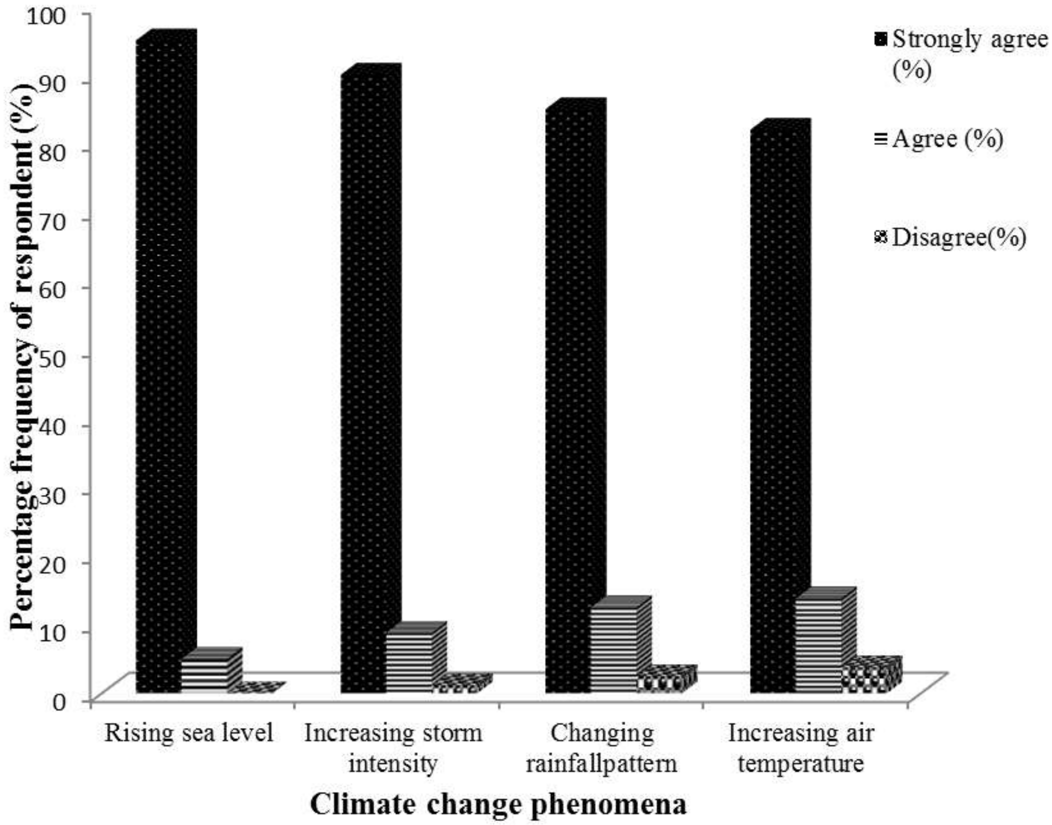

Figure 14: Respondents perception to the observed changes in climate (n=220)

Figure 15 shows that, majority of the respondents (78.8%) strongly agreed that observed changes in climate of the community is due to some human induced activities in the community such as mangrove cutting, sand winning and charcoal burning. 27.5 agreed whiles about 5% disagreed.

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Figure 15: Respondents Perception to the Causes of Changes in Observed Climate (n=220)

Community Perception of the Impacts of floods and drought on Assets and livelihoods

Impacts of flood on community assets

Figure 16 shows the perception of the respondents to the impact of floods on the assets of the community. 95% to 80% of the respondents are of the view that floods has a very high negative impact on the assets, 75% to 70% are stated that the impacts of floods on the assets are high, 40% indicated the impact is medium whiles 10% to 5% are of the view that, the impact of flood on assets is low.

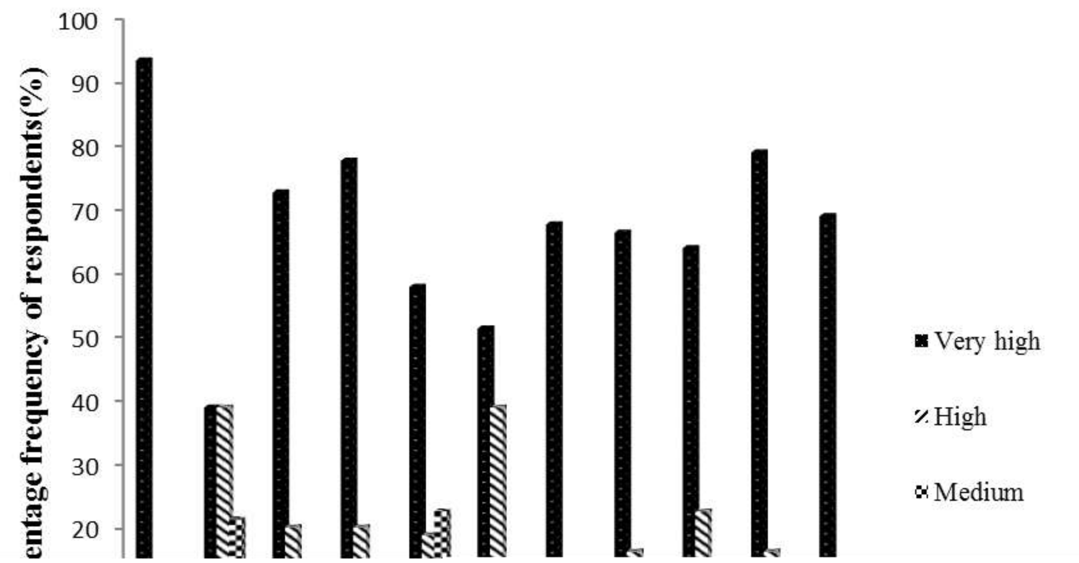

Figure 16: Respondents Perception to the impact of flood on assets

Impact of flood on fisheries based activities

Figure 17, shows the perception of the respondents on the impact of flood on fisheries based livelihoods. Majority of the respondents 95% to 88% indicated flood has a very high negative impact on these activities, 25% to 10% are of the view that, the impact is high whiles 5% were of the view that the impact of flood is low on fisheries livelihoods.

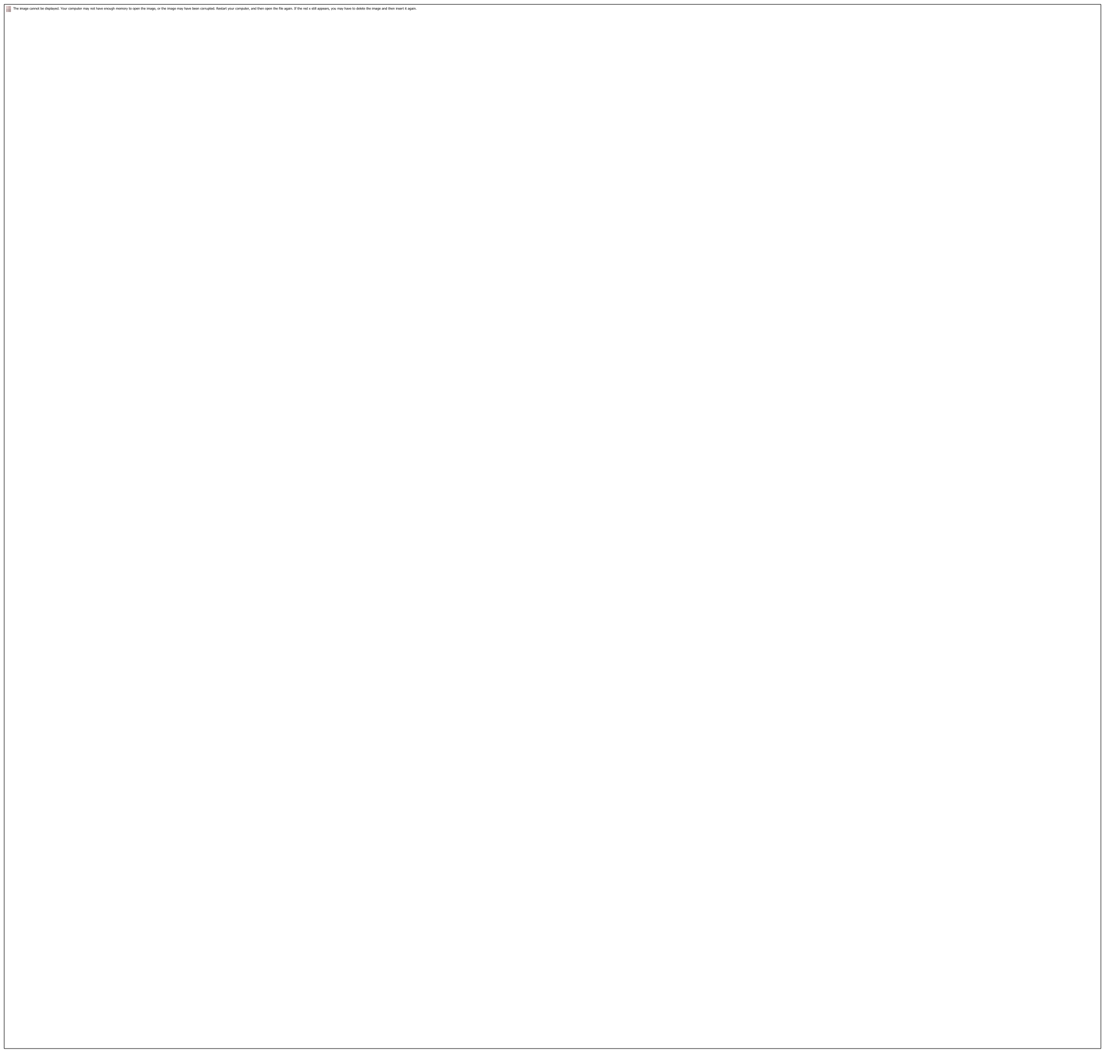

Figure 17: Respondents Perception to the impacts of flood on fisheries based activities

Impact of Drought on Fisheries Based Activities

Figure 18 shows the perception of respondents on the impact drought on fisheries based livelihoods. 95% of the respondent indicated drought has a very high impact negative on fisheries activities, 25% are of the view that the impact of drought is high on the activities and 10% to 5% mention the impact to be low on activities.

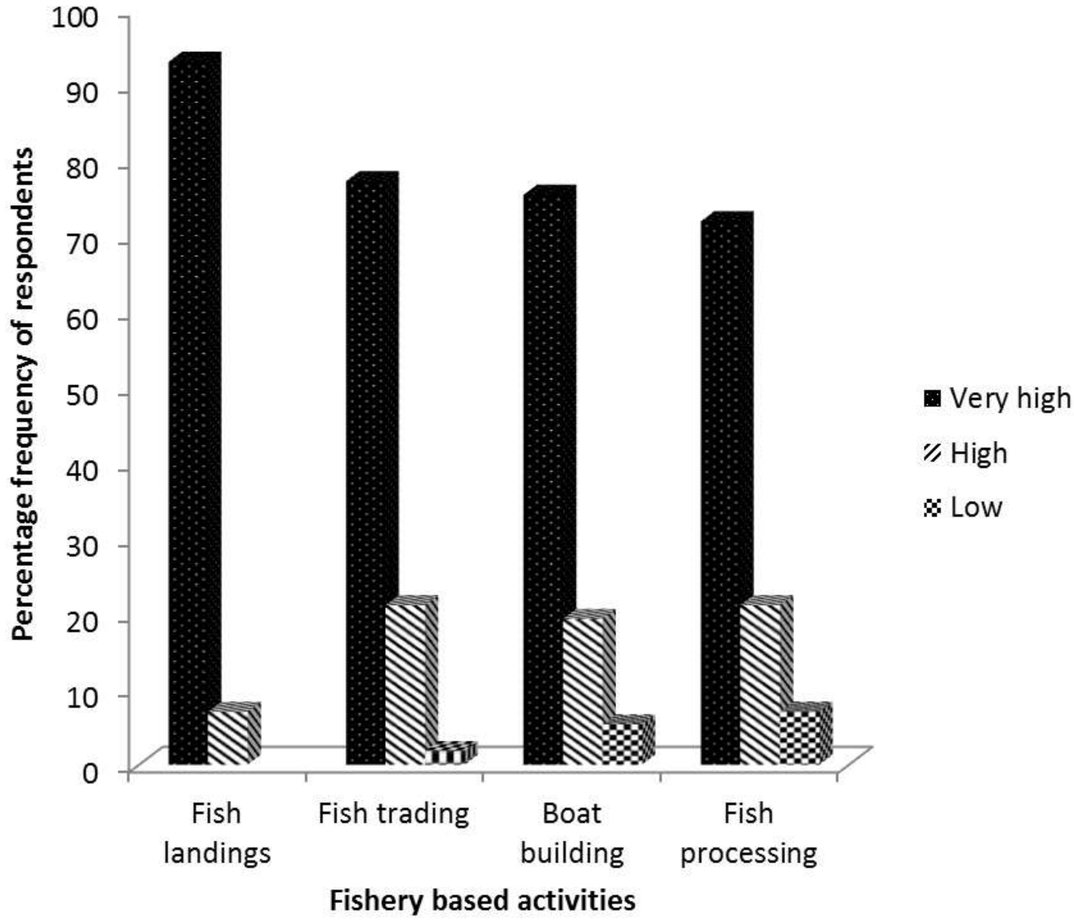

Figure 18: Respondents perception on the impact of drought on fisheries based activities

Impact of flood on non- fisheries based activities

Figure 19 shows the respondents perception on the impact of flood on non-fisheries based activities. 70 -86% of respondents interviewed mentioned flood have a very high negative impact on crop farming, animal farming and small scales business, 40- 50% are of the view that, the impact is high whiles about 10% of the respondents stated the impact is low on non-fisheries based activities.

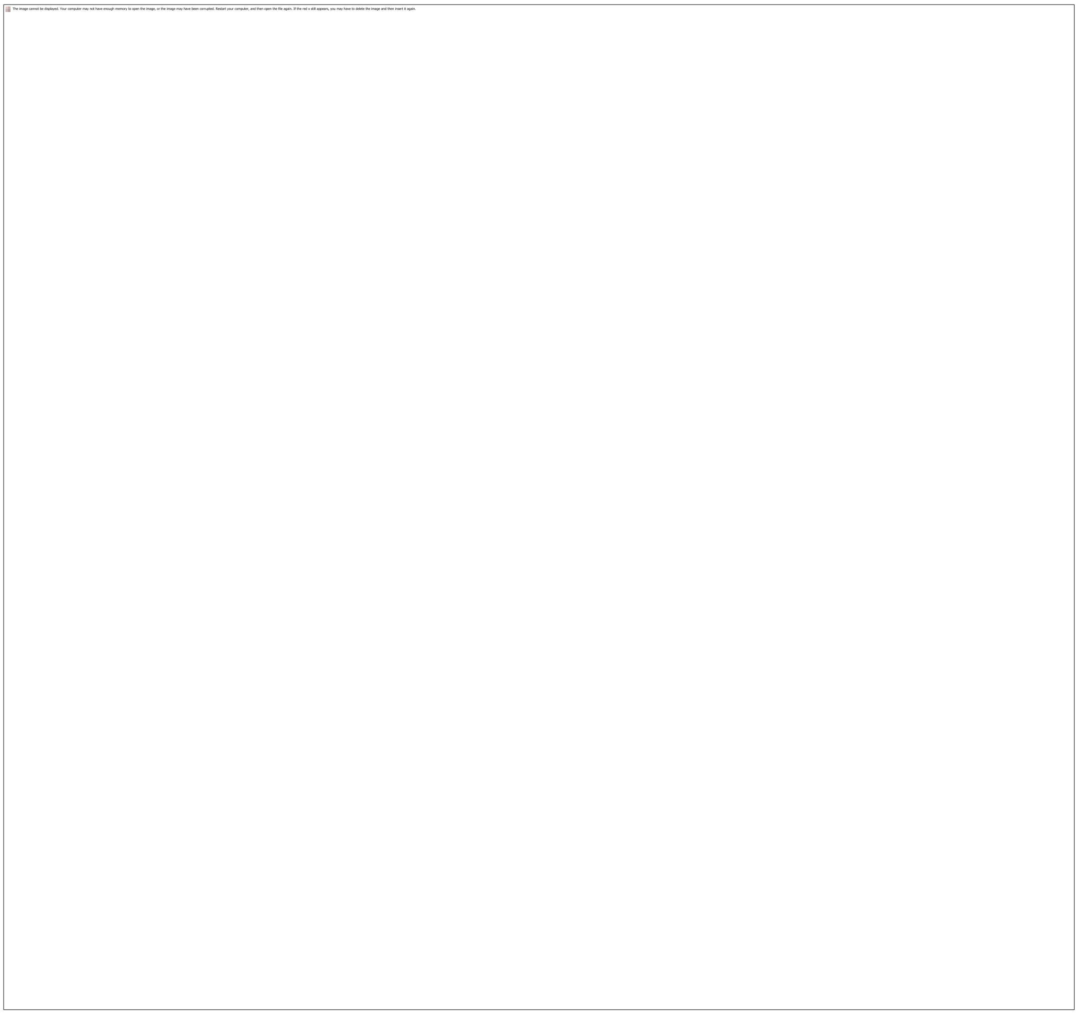

Figure 19: Respondents Perception to the impact of flood on non-fisheries activities at Akwidaa

Impact of drought on non-fisheries based activities

With respect to Figure 20, Majority (70-90%) of respondents interviewed were of the view that, drought has a very high negative impact on crop farming, animal farming and the small scale business. 10 to 50% also mentioned that, the impact of drought is high whiles 5 to 10% are of the view that the impact is low.

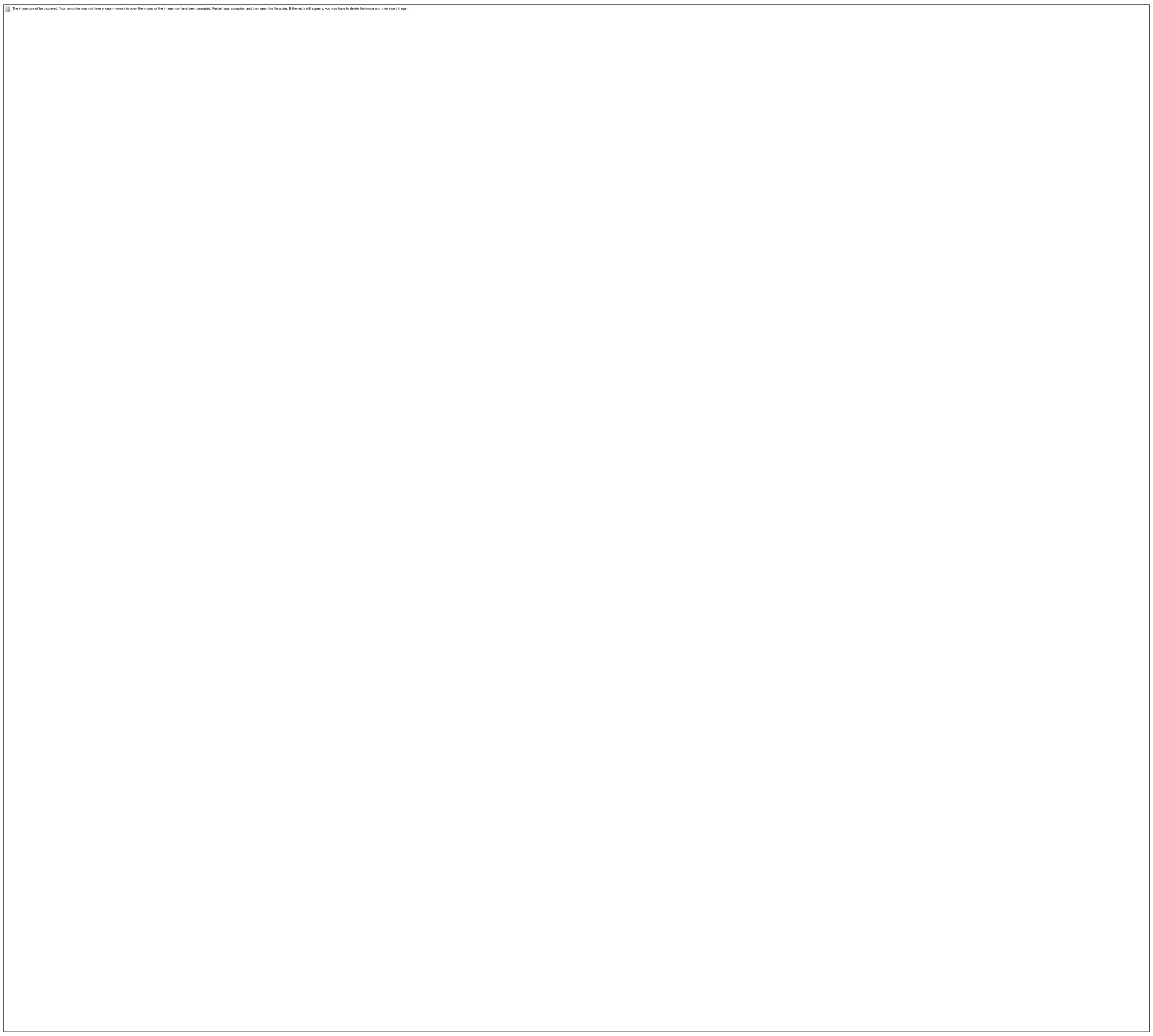

Figure 20: Respondents Perception to the impact of drought on non-fisheries activities

Vulnerability trends of Assets and Livelihoods to drought and flood

Vulnerability of Community Assets and livelihood to drought

Figure 21 shows the vulnerability of the assets and livelihoods in the community to drought. The trend reflects a general increase over the last four decades. The trend was generally low from 1970- 1982. Vulnerability trend was higher thereafter until 1995, reduced slightly to 2005. The trend is seen to increase gradually and stabilizing from 2005 to 2012. Fisheries based livelihoods have been more vulnerable to drought over the period assessed with a vulnerability value of about 6mmhr^{-1}, followed by the non-fisheries with a value of about 5 mmhr^{-1} and assets 4 mmhr^{-1}.

Vulnerability of Community Assets and livelihood to flood

Figure 22 shows the vulnerability of the assets and livelihoods in the community to flood. The trend reflects a general increase over the last four decades. The trend was generally low from 1970- 1982. Vulnerability trend was higher thereafter until 1995, reduced slightly to 2005. The trend is seen to increase gradually and stabilizing from 2005 to 2012. Assets (houses, schools, bridge etc.) have been more vulnerable to flood over the period assessed with a vulnerability value of about 29.5mmhr^{-1}, followed by the non-fisheries with a value of about 21.5 mmhr^{-1} and assets 11.4 mmhr^{-1}

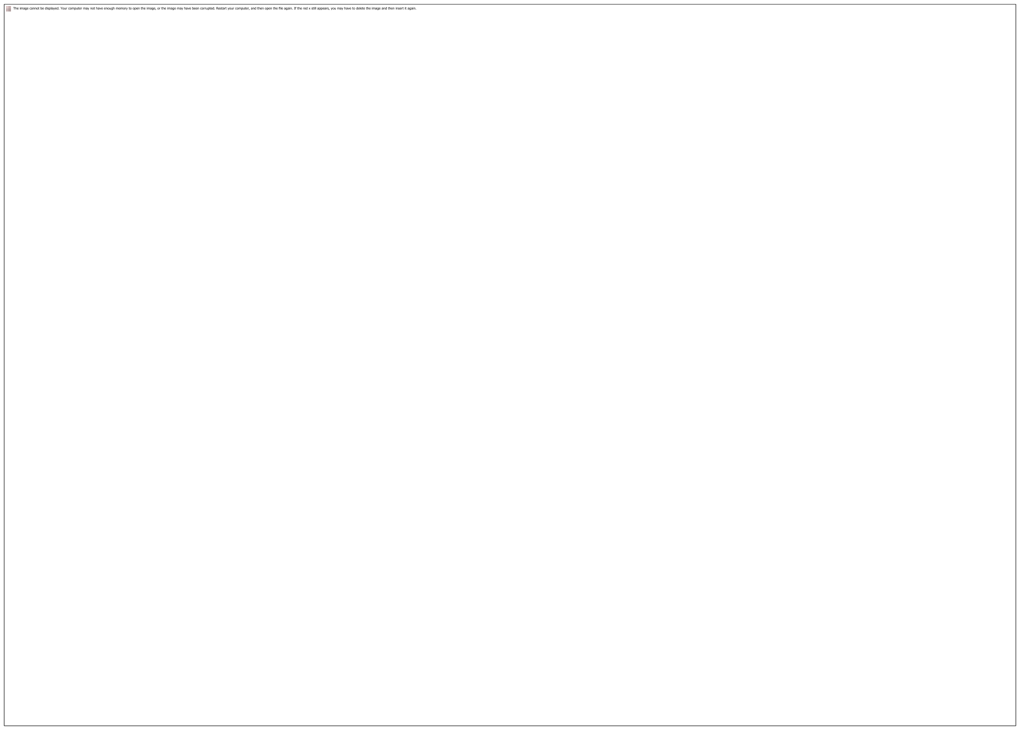

Figure 21: Vulnerability of community assets and livelihoods to Drought

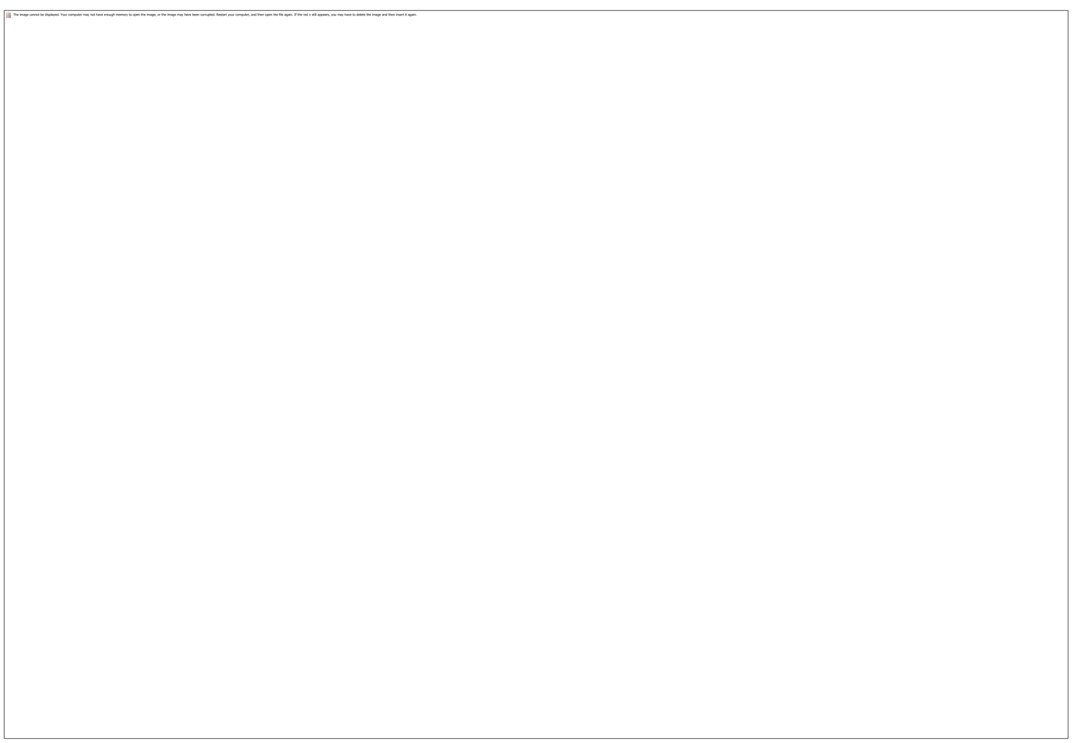

Figure 22: Vulnerability of the community assets and livelihoods to flood

Estimation of the adaptive capacity of the people to drought and flood

The Table 1 to 5 shows the various impacts of drought and flood on assets and livelihoods and the adaptive capacity employed by the community. It also shows how the adaptive capacity of the community to drought and flood impact were estimated based on the ratios of the total adaptive capacity of the community to the totals of the best adaptive practices in literature using equation 3 and 4.

The table 6 shows how the sensitivity of the community is to the impact of drought and flood. The sensitivity was derived based on the ratio of the resources available in the community against the recommended resources to make the community less sensitive to the impact using equation 6.

Table 1: The adaptive capacity of the Akwidaa community to the impact of flood on non-fisheries activities

Vulnerability variable	Best Practices in literature	Score(1)	Community Adaptation Strategies	Score (0-1)
Washing away of top soil making soil infertile	Government policies should ensure that the terms for credit in the banks are flexible to enhance farmers access to affordable credit, which increase their ability and flexibility to change crop and soil management strategies in response to climate change (Deressa et al., 2009)	1	No coping strategy	0
Destruction of crops by flood (cassava)		1	No coping strategy	0
Animals killed and carried away by water during flood	Improving the skills and knowledge of extension service personnel about climate change and adapted management (Gbetibouo,2009)	1	No coping strategy by community	0
Exposure of business and trading structures to water	Provision infrastructure (NCCSAP,2007)	1	No coping strategy	0
		Total=4		**Total=0**

Table 2: The adaptive capacity of the Akwidaa community to the impact of flood on fisheries based activities

Vulnerability Variable flooding	Adaptation Strategies by community	Score (0-1)	Best Practice in literature	Score (1)
Broken/destruction of canoes by flood	No coping strategy	0	Construction of sea defense wall	1
			Construction of a landing site	
			(EPA, 2000 and Ghana National Climate Change Policy)	1
Prevention of costumers from buying and selling fish	Community members wait for the water to dry up before buying fish	0	Enforcement of building guidelines in coastal locations	1
			Construction of a landing site	1
			(Adelekan, 2010)	
Exposure of stored fish to water	Properties brought outside of kitchen to be dried	0	Present of storage facilities	1
			Building on stilts (Adelekan, 2010)	1
		Total=0		**Total=6**

Table 3: The adaptive Capacity of the Akwidaa community to the impact of drought on fisheries activities

Drought on fisheries activities	Best Practice in literature	Score (1)	Community Adaptation Strategies	Score (0-1)
Exposure of landed fish to excess heat	Availability of good storage facilities	1	Alternate source of livelihoods (farming and trading)	1
	Alternate sources of livelihood (Daw et al., 2005 and EPA,2000)	1		
Destruction of canoes by heat	Presence or Construction of landing site	1	No landing site and coping strategy	0
Exposure of stored smoked fish to heat	Diversification livelihoods (EPA,2000 and GNCCP,2012)	1	Alternate livelihoods	1
		Total=4		**Total=2**

Table 4: The adaptive capacity of the Akwidaa community to the impact of flood on community assets

Effects of flood on community assets	**Community Adaptation Strategies**	**Score (0,½,1)**	**Best Practices in literature**	**Score(1)**
Deterioration of buildings (Houses, roads, etc.)	Renovation of buildings	½	Relocation and building on stilts (EPA,2000)	1
	Movement of household properties	½	Construction of drainage systems (NCCSAP,2009)	1
	Filling of road with sand and wood shavings	½		
Destruction of household properties	Relocation of properties	½	Enforcement of building guidelines in coastal locations	1
			Relocation of community IPCC (2001)	1
		Total=2		**Total=4**

Table 5: The adaptive capacity of community to the impact of drought on non-fisheries activities

Effects of drought on non-fisheries activities	Best Practice in literature	Score(1)	Community Adaptation Strategies	Score(0-1)
Increased temperatures reduce the time the crops can be stored without refrigeration	Diversification Livelihoods (Fosu- Mensah et al., 2010)	1	Alternate livelihoods	1
Withering of crops as a results of exposure to intense and prolonged sunshine	Plant short season variety crops (Fosu- Mensah et al., 2010)	1	No coping strategy	0
High temperatures causes vegetables to ripen permanently	Diversification of livelihoods (Daw et al., 2009)	1	No coping strategy	0
		Total= 3		**Total= 1**

Table 6: The sensitivity of community assets and livelihoods to drought and flood

Community assets	Resources available in community	Score (1-0)	Recommended Strategies based on field observations	Score (1-0)
Roads	Deplorable feeder roads	1	Tarred roads	0
Clinics	Concrete building but inadequate facilities	0.5	Concrete structure with adequate facilities	0
Bridge	Wooden Bridge	0.5	Metal or Concrete bridge	0
Houses	Mud and Wooden structures	1	Block or concrete structures	0
Markets	Unplanned market with weak structures	1	Well Planned markets(Accessible with stalls)	0
Schools	Concrete structure with inadequate facilities	0.5	Concrete structures with adequate learning and teaching materials	0
Mangroves	Degraded mangroves ecosystems	1	Transformed mangrove ecosystem	0
Landing site	No landing site	1	Landing site	0
Storage facilities	No storage facilities	1	Storage facilities/ Electricity	0
Culverts/Gutters	Weak drainage systems	1	Well structure culverts and gutters	0
Total		**9.5**		**0**

CHAPTER FIVE

DISCUSSION

Evaluation of community perception on causes of climate variability with respect to real time meteorological conditions

Akwidaa is a coastal community situated on a strip of land surrounded by the sea and a lagoon. Ecologically, this means the area is influenced by the sea and geographically by some arbitrary distance inland away from the high tide level. The community therefore depends on the sea and interconnected ecosystems for their livelihoods. Climate variability manifesting in erratic rainfall, sea level rise, increase in temperature and coastal erosion are among the myriad challenges confronting the people of Akwidaa in recent decades. Therefore gaining first-hand information on the causes and effects of climate variability at the local community can best be obtained from the local inhabitants who are a key part of the system. This aspect of the study was conducted against this background.

Observed changes in temperature

The humid climate of Akwidaa is influenced by its coastal location and characterized by two distinct seasons, a wet season from June to October and a dry season from November to May. The climate trends in Akwidaa generally indicate that, temperature have continued to rise steadily. These observations match with other studies on climate in West Africa (Nicholson, 2001; 2005; IPCC, 2007; Shanahan et al., 2009). Results of the study indicate that 95% of the respondents in the study area have noticed changes in temperature over the last 30 years and consider such changes a threat to the assets and livelihoods in the community. Members of the community also indicted that temperature has increased in the community over the last 30 years. Analysis of temperature data obtained from the Ghana Meteorological Agency over the last 4 decades for the study area shows an increase in temperature of about 0.2^{o} C confirming the community's observation.

Globally, particularly for developing countries, deforestation has been noted to be a driving factor of climate variability. Deforestation contributes to the build-up of CO_2 in the atmosphere by reducing the rate at which the CO_2 is removed from the atmosphere and also by the decomposition of dead vegetation and burning biomass (Mastrandrea and Schneider, 2005). However in Africa and Ghana in particular, where industrialization is very low, deforestation remains a major source of CO_2 emissions. Tropical forests apart from their role as reservoir or sinks as well as sources of carbon also provide numerous additional ecosystem services including, reduced sunlight which directly or indirectly influence climate (Betts, 1999). Between 1990 and 2005, Ghana lost 25.9% of its tropical rain forest cover, or around 1,931,000 hectares at 2% per annum (FAO, 2007). Deforestation in Ghana has generally been driven mainly by agriculture and logging. Mangrove ecosystems which have been reported to store about 1000 tons of carbon which is three times much as the average tropical rain forest are also been degraded for developmental purposes (UNEP, 2008). Globally, blue carbon generally known to be carbon stocks of mangroves is approximately 18.45 $TgCyr^{-1}$ is derived from a global area of 160,000km^2 (Chmura et al., 2003). The continued increase in temperature in the study area could be attributed to the degradation of this forest which might have increased the emission of greenhouse gases. The pronounced increases in ambient temperatures in the area from 1970-2012, seem to be following expected global trends (Goddard Institute for Space Studies, 1994). The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (IPCC, 2007) states that global mean surface temperatures increased over the last 30 years. The meteorological data for the study area analyzed from 1970-2012, shows that temperatures are becoming so high.

Observed Changes in Rainfall

Inhabitants of Akwidaa indicated that they observed changes in the rainfall pattern, which has decreased gradually in the community over the last 30 years. The analysis of rainfall data obtained from the Ghana Meteorological Agency revealed a gradual decrease in rainfall in the study area over the last four decades. However, extreme and heavy raining days exposes the community to floods. Human activities such as mangrove cutting, sand winning and charcoal burning have contributed in exposing the community to floods leading to some severe impacts.

Mangroves provide efficient buffer for coastal protection as their complex structure attenuates wave action, causing reduction of flow and sedimentation of suspended material (Alongi, 2008). Although, the causal link between mangroves and coastal protection is not always straight forward (Alongi, 2008), this function of mangroves forests also is likely to act as an important buffer against flood that exposes the coast to the impact of erosion. The decreasing intensity of rainfall in the study area correlates with the relative humidity. Humidity which is an indication of the level of moisture in the atmosphere has also decreased gradually over the last four decades. High relative humidity means higher moisture content in the atmosphere that signals the possibility of rains. The decline in relative humidity in the study area is indicative of low atmospheric moisture levels indicative of a low potential for rainfall. Low rainfall intensity indirectly affects the flow of river systems. At higher relative humidity, there is more water in the atmospheric system and this also reduces evaporation which is major source of water loss. Rainfall variability observed in the study area is not different from what has been observed in most parts of Ghana.

According to Le Borgne, 1990; Servat et al. 1997 and EPA, 2000), decreases in rainfall has resulted in a significant decrease in water resources. Some researchers have concluded that the decline in rainfall has been very drastic to suggest a significant change in the normal regional climate (Farmer, 1985 and GNCCP, 2012). The slight increase in rainfall in the study area from the year (2000s) onwards is reflective of the West African trend (Nicholson et al. 1996). The observed changes in Akwidaa, though very good and encouraging, it cannot be concluded that the rainfall pattern has changed to a wetter regime because analysis of historical rainfall in other parts of West Africa by Ozer et al., (2003) shows that statistical tests responded with a relatively long time lag to strong variations. Ozer et al., (2003) suggested that a further ten years should be allowed to elapse before making any conclusions regarding rainfall regimes. Rainfall pattern in the study area has decreased by 20mm over the last 30 years and is highly unpredictable which was not the case in 1970's. The general lack of enforcement of the environmental laws, as were identified by the respondents in the study, may be the possible explanation why mangrove cutting, sand winning activities, deforestation and charcoal burning are being practiced. There is therefore the need for law enforcement in the community to reduce the effects of the changes in climate to the community.

Assessment of the perception of the community to impacts of floods and droughts on assets and livelihoods

Impacts of flood on assets

Coastal settlements, infrastructure, habitats and human population are vulnerable to varying degrees of floods and droughts as climate-related risks (IPCC, 2007). According to Nott (2006), the causes of floods can be broadly divided into physical factors such as climatological forces, and human influences such as vegetation clearing and urban development. The most common causes of floods are climate related, most notably rainfall. Prolonged rainfall events are the most common cause of flooding worldwide. These events are usually associated with several days, weeks or months of continuous rainfall. Human impacts on river catchments influence flood behavior. Land use changes in particular have a direct impact on the magnitude and behavior of floods (Nott, 2006). Deforestation results in increased run-off and often a decrease in channel capacity due to increased sedimentation rates.

The present study revealed that flood has a very high impact on the assets of the area according to majority of respondents (90%). A substantial number of productive and non-productive assets have been damaged by floods in the community. Some productive assets include fishing nets; farming tools whiles non-productive assets such as properties have been lost. Most of these losses were attributed to household proximity to flood prone areas and human activities such the clearing of vegetation along the coast which reduces the risk of flood and sand winning activities in the community. This could also be attributed to the fewer resources available in the community to cope with flood events. This result has been supported by other studies conducted globally. Work done by living with Risk (2006) shows that, the frequency of floods has been increasing over the past 30 years, resulting in loss of life, damage to property and destruction of the environment. The number of people at risk has been growing each year and the majority is in developing countries with high poverty levels making them more vulnerable to disasters.

Grunfest (1995) argues that due to high poverty levels, people have become more vulnerable because they live in hazardous areas including flood plains. They have fewer resources which makes them more susceptible to disasters. They are less likely to receive timely warnings. Furthermore, even if warnings were issued, they have fewer options for reducing losses in a timely manner. The poverty level affects the resilience and process of recovery from disasters. The Third World Water Forum on poverty and floods held in March, 2003 indicated that in recent years ,floods had become more frequent and of increasing severity resulting into loss of life, injury, homelessness, damage to infrastructure and environment as well as impacting on other critical sectors such as education and agriculture. Work done by the WMO (2006), showed that social impacts are linked to the level of well-being of individuals, communities and society. It includes aspects related to the level of literacy and education, the existence of peace and security, access to basic human rights, systems of good governance, social equity, positive traditional values, knowledge structure, customs and ideological beliefs and overall collective organizational system (Living with Risk, 2002). Other studies conducted by GNCCP (2012) and the EPA (2000) also indicated the clear manifestation of floods and it impacts in the south- western, greater and eastern part of Ghana on infrastructure and water resources. This is evident that floods and it impact are already being felt on Ghana coast.

Impacts of drought on fisheries based activities

Drought can occur when the temperature is higher than normal for a sustained period of time; this causes more water to be lost through evaporation. Other possible causes are delays in the start of the rainy season or timing of rains in relation to principal crop growth stages (rain at the "wrong" time). High winds and low relative humidity can make matters much worse (WMO, 2006). Temperature has been recognized a key climate factor that affect fisheries globally. Populations of fish and other aquatic organisms are greatly influenced by several factors such as physical, chemical, biological and meteorological factors with temperature being the leading factor. Increased temperature affects the metabolism, physiology and behavior of fish, food consumption and nutrient levels in water (Winberg, 1960 and Jorgensen, 1976). Metabolic activity in fish increases by 10% for every 1°C rise in temperature of the aquatic environment, i.e. fish need 10% more oxygen for every 1ºC rise in temperature (IPCC, 2007). Waters of the globe has been reported to contain a complex mixture of gases. Among gases, dissolved oxygen has been reported the most important limiting factor in the aquatic system (Huet, 1972; Brown and Gratzek, 1980). The requirement of fish for dissolved oxygen varies with temperature (Elmon and Hayes 1960). Increased temperature also has been reported to interfere with coastal upwelling events. With temperature increasing, upwelling phenomena which increase the productivity of fishes will be altered and there will be reductions in catches and productivity (GNCCP, 2012). The above studies have been confirmed by Barges and Fonteneaus (1980) who reported that increased temperatures influences the distribution, catchability, productivity and seasonality of fishes in the Gulf of Guinea upwelling areas. Ocean acidity has also been reported to be influenced by temperature (IPCC, 2007). Ocean acidification increases with increasing temperature which affects also the productivity of some shellfish, zooplankton and phytoplankton which serves as primary productivity for fishes (EPA, 2000).

The results of the study show that drought has a very high impact on fisheries based livelihoods (fishing, trading and processing) according to majority of the respondents (90%) due to the increased in temperature. The high negative impacts could be attributed to the changes in temperature. The rise in temperature might have affected the catchability and productivity of fish in the community as confirmed by the above studies. This have resulted in the decline in fish catch and fisheries activities observed in the community with the increasing temperature.

Impact of flood on fisheries livelihoods

Considering the enhanced effect of climate change induced flooding and other activities along the coastal areas, flooding adverse impact would definitely be compounded on most fisheries structures, especially the artisanal sector would be submerged. Flooding has been reported to need moderate priority attention (Agboola and Olurin, 2003). The Nigerian Environmental Study/Action Team (NEST, 2004), reported that heavy rains will not only worsen the problems of flooding, but are already a menace in Africa. The associated inundation will increase problems of floods, intrusion of sea-water into fresh water sources and ecosystems destroying such stabilizing system as mangroves and fisheries (EPA, 2000). One most probable reason that would have warranted flood and erosion within Africa to be ranked moderate is the fact that the region lacks adequate meteorological data, especially in the area of rainfall data and tidal measurements (Safe Earth Consult Ltd, 2011). Coastal vegetation such as mangroves which enhances fish productivity by serving as breeding and spawning grounds have been lost to coastal erosion and flooding (Uyigue and Agho, 2007).

Results of the study area show that, floods have a high impact on fisheries based activities in the community. About 90% of the respondents mentioned floods have a high impact on fisheries livelihoods especially on trading and smokers and storage structures. The high impacts of floods on these activities in the community could be attributed to the weak infrastructures and lack of meteorological data or early warning systems against flood events in the community. The high impact of flood on fisheries in Akwidaa could also be due to the lack of coastal resources management and risk awareness and emergency response both at the district and community level.

Impacts of drought on Non-fisheries livelihoods

Crop farming is the major non-fisheries based activity in the community; however the result of the study area shows that drought has a very high impact on these activities especially on crop farming. The impact of drought in the study area could be attributed to the increasing rise in temperature observed over the last 30 years in the community coupled with weak adaptation strategies to reduce the risk. The locals practice subsistence farming thereby feeding on the crops they grow as well as sell some to earn income, but farming in the community is severely affected temperature. The effects of temperature on farming also affect the nutrition and health of the people as they grow what they eat. For example cassava and cocoyam, which are very important components of fufu, a staple food of the people in Akwidaa are being affect by the higher temperatures. Other crops grown include maize and vegetables are also affected. The farmers have realized that temperature is already impacting on the crops they grow but other factors like species or cultivar and the soil type (Sagoe, 2006) may also affect the growth of crops in the Akwidaa, aside the change in climate. In an assessment of the effects of drought on root crops production, Sagoe (2006), using the 1990/1991 rainfall data as the base year and assuming rainfall amounts remain the same, increasing temperature in 2020, 2050 and 2080 by 0.6 ºC, 2º C and 3.9º C will respectively reduce cassava yields. The rate of reduction in cassava yields increased with an increase in temperatures, and projects that cassava yields would decrease by 13%, 23% and 58% (observed Kumasi yields) and 3%, 13.5% and 53% (predicted yields) in 2020, 2050 and 2080 respectively. Percent reductions in cocoyam productivity at the same projected conditions for temperature are 11.8%, 29.6% and 68% in 2020, 2050 and 2050 respectively. Such a reduction in production of these staple crops with an estimated per capita consumption of 151.4 kg of cassava and 56 kg of cocoyam, accounting for 58% of the per capita food consumption would not only have a direct impact on the local farmer but also on the national economy.

Root and tuber crops as part of the agriculture exports generate about 75% of government earnings and employs 70% of the population. Already, farmers in the Akwidaa community have started moving from the cultivation of these tubers due to low yield into vegetable production. Maize has a very high crop water requirement (CEEPA, 2006) and the reduction in water availability in Akwidaa will have serious consequences on maize production because crop water availability, in general, is directly related to the crop yield; this holds for all crops. In a study of five crops (maize, millet, sorghum, groundnuts and bean) in selected countries across Africa, CEEPA (2006) found maize as the least drought resistant and the most sensitive to water stress. In the case of rainfall, actual yield increased from 0.8 tons/ha when actual crop water use was 212 litres to 2.26 tons/ha when actual crop water use was 38 litres, showing the important role of water in rain-fed maize production. The CEEPA (2006) findings corroborate the well-known fact that water is among the main limiting factors in several African farming systems including that of the study area. This, unfortunately, is likely to be the real situation if no immediate steps are taken to address the situation as de Wit and Stankiewicz (2006) predict that by the end of this century 25% of Africa will have reduced surface flows owing to decreasing rainfall.

Impacts of floods on Non-Fisheries livelihoods

Majority of the respondents (90%) indicated that floods have had a high impact on production from farming. Crops fields are damaged by floods and top soil washed away. Mostly affected crops are roots and tubers e.g. cassava resulting in reduced staple crop production and hence reduced food security. The findings provide a better understanding of the vulnerability of the community due to their over dependency on crop production as one of their main livelihood source.

Vulnerability of the community to drought and flood

Vulnerability in the context of climate change means the risk that climate change will cause a decline in the well-being of people (especially poor) and countries. This means the degree to which a system is susceptible to, or unable to cope with adverse effects of climate change, including variability and extremes (WMO, 2006). The ultimate effects of climate change on socio-economic or ecological systems depend on the interplay of three factors namely, characteristics of climate change, the sensitivity and adaptive capacity of the system to climate change. Societies or communities that are especially sensitive or are least able to adapt are the most vulnerable (IPCC, 2014). The vulnerability of people in a given area to the effects of climate change depends on the surrounding landscape unit to weather extremes and climatic shifts and the adaptive capacity of the local population (WMO, 2006).

The present study revealed that, the livelihoods (fisheries and non-fisheries) and assets of the community have been vulnerable to the impact of flood and drought. The fisheries based livelihoods have been more vulnerable to drought whiles assets have also been more vulnerable to flood over the last four decades. As discussed above, communities that are especially least able to adapt are the most vulnerable to the effects of climate change. Vulnerability, which is also a function of adaptive capacity and capacity to cope, includes access to technology, infrastructure, information and effective institutions skills (IPCC, 2014).

The increasing vulnerability of the people to drought and flood could be attributed to the fact that their adaptive capacity is weak as seen in the estimation of adaptive capacity and also the changes in climate especially temperatures. The last 10 years of the trend shows that, their vulnerability to drought is stabilizing. This could be attributed to the fact that, the community might have learned to live with the problem or might be coping gradually with the effects of drought. This is due to presence of some culture practices in the community which enables them to manage their resources and also the use of indigenous coping strategies to help them reduce the impact of the climate induced risk. Widespread nature of poverty in the country, reliant on primary production, high population in the community and over dependence on rain fed crops are partly the reasons for the vulnerable nature of the community to impacts of climate variability. This is particularly so in the community owing to inappropriate adaptive policies, lack of significant investment of incomes coupled with inadequate institutional skills. Decreasing the vulnerability of socio economic sectors and ecological systems to natural climate variability through a more informed choice of policies, practices and technologies will, in many cases, reduce the long-term vulnerability of these systems to climate change (IPCC, 2000a). While members of the scientific community and policy-makers are particularly concerned about adaptation to climate change, some authors (e.g., Burton 1992; IPCC, 2007 and GNCCP, 2012) have argued that attention should be given to adaptation to current climate.

Bohle et al., (1994) argued that a full understanding of current vulnerability is necessary for developing strategies to coping with future climate change. This school of thought stresses the potential benefits and enhanced resilience that can result from practices and infrastructure that are well suited to the current climate. Given the uncertainties about future climate under various scenarios, efforts to assess adaptation to current climate can be useful as improved adaptation to current climate may be a crucial step in reducing vulnerability.

Burton (1997) argued that for developing countries it makes sense to focus on current problems that affect the economy rather than on uncertain changes that will only be manifested at some point in the distant future. It is in this context that current vulnerability is likely to be most relevant. The same author points to the need for more convergence between the scientific communities studying adaptation to current climate and extreme weather and those studying longer-term changes advice which seems to have been taken by the IPCC. From this point of view (i.e., those adversely affected by climate change), distinctions between normal climate and climate change might be irrelevant.

CHAPTER SIX
SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Introduction

The chapter deals with a summary of the research procedures used, major findings, conclusions and recommendations put forward by the researcher.

Conclusions

Climate change has been accepted both scientifically and politically to be occurring and most studies point to the fact that poor, natural resource-dependent rural households will be the worst hit by adverse climate impacts (`IPCC, 2007). The issue of climate variability in Akwidaa may not be a new issue and the community has coped with the effects of the varying weather conditions on their livelihoods and assets for a long time. However, the magnitude of recent changes in climate is what is of major concern. If the changes in rainfall and temperature continued to be very negligible as it had been previously, the people would have continued to cope quite well with their indigenous knowledge and practices and their limited resources without any major problems. Current changes in climate are far beyond what can be called negligible. True changes in climate are occurring in Akwidaa and the effects on assets and livelihoods in the community are already being felt as seen in the results of the study. There is therefore an urgent need for assistance to this community to enable them adapt to the changes. Drought and flood had negative impact on the livelihoods in Akwidaa over the last four decades. Also, the community's livelihoods and options have been vulnerable to drought and drought. There is therefore the need for the implement for proper adaptive capabilities

Recommendations

The recommendations are in the form of proposed adaptation strategies which when implemented can enhance the community's adaptation strategies to the effects of climate change. There is no argument about whether the climate is changing or not. Through greenhouse gas emissions, the planet has already been committed to some form of change and what is needed is for us to adapt to the coming changes (adaptation) whilst we find means of preventing further high levels of greenhouse gas emission. Although this document may make references to mitigation because it believes that there is a need to reduce the emission of greenhouse gases and stop the worsening of the climate, the central focus is Adaptation because climate change cannot be totally avoided, and already the people are feeling the negative impacts of climate change.

Moreover, mitigation measures may take time to become effective because the climate system is already set in a particular direction, some greenhouse gases are already in the atmosphere. The proposals for adaptation strategies are made at both the National and Community levels. Most of the community level adaptation strategies being proposed can work best when implemented within a national adaptation strategy framework. Since the vulnerable people are already coping using their limited resources and indigenous knowledge, the government‘s adaptation strategies should be built on already existing information about community capacity, knowledge and practices the people are using to cope with climate hazard. This is a sure way of ensuring effective adaptation. This section proposes adaptation strategies which can be implemented at the local or community level.

Community assets

Good coastal governance in the context of local individualities is therefore key to meeting the challenges of climate change in communities such as Akwidaa. A range of measures to increase the adaptive capacity of the community which governments at different levels should pursue include;

i. The restriction of land reclamation activities in newly developing areas

ii. Construction of more drainage systems taking into consideration storm runoff responses under high intensity rainfall,

iii. Monitoring of the community's development, proper solid waste management and environmental education for the members of the community.

iv. Enforcement of building guidelines in the community is also particularly important.

v. Relocation of community from the old town to the new town

vi. Elevation of buildings above the flood level, either on piles or a mound

vii. Provision of post disaster recovery and compensation by government to the community to help them recover from the impacts of climate induce risk.

Non-fisheries based activities

The main non-fisheries activities in the community are crop farming and trading and it is highly vulnerable to current and projected climate changes. Below are some proposed adaptations for the community to improve on their farming activities.

i. Improved Mixed Cropping and Mixed Farming

The farmers traditionally practice mixed cropping especially with food crops. Mixed copping or crop diversification guarantees the chances that at least one of the crops grown will survive even when the weather becomes unfavorable. This system must be improved for the benefit of the farmers. Some crops like groundnuts, pigeon peas and soybean which are traditionally not grown by farmers in the community can be introduced on pilot basis in the community. These are high value leguminous crops which if incorporated in the mixed cropping systems, have the potential to improve soil quality. Furthermore, these crops also require less water and tolerate drought and short rain incidences better than most of the crops the farmers currently grow and are not yielding much because of lack of rain. Moreover, it has been realized that mixed crop and livestock farmers are associated with positive and significant adaptation to changes in climatic conditions compared to specialized crop and/or livestock farmers. The results imply that mixed farming systems are better able to cope with changes to climatic conditions through undertaking various changes in management practices

ii. Soil quality

The farmers expressed concern reduced soil fertility and low yield of crops and advocated the use of chemical fertilizers, the cost of which they could not afford. To improve soil fertility, whilst reducing mineral fertilizer use and on-farm energy costs, the use of soil conservation practices such as minimum tillage, application of animal manure, cover cropping, mulching and composting are proposed for the rural farmers. The farmers should be introduced to methods to improve soil fertility using organic manure instead of chemical fertilizers. Instead of burning vegetative material from the farms during land preparation (mainly through slash and burn), the farmers should be helped to develop composting techniques that will use the vegetative materials produced from their farms.

Fisheries based activities

Below are some proposed adaptations for the fisheries activities in the community to reduce their vulnerability to climate induced risk.

i. Infrastructure provision (e.g. storage facilities, protecting harbors and landing sites) to improve fish market, quality and to be able to store surplus fish from going bad.

ii. Capacity building training programs for the community to educate them on climate change issues and the appropriate adaptation measures against the impacts.

iii. Diversification and Alternate sources of livelihoods: With the support of government, more job opportunities should be provided in the community to improve on the living standards of the community. The government has a major role to play in the adaptation efforts of local populations by creating the right atmosphere in terms of policy and institutional frameworks to guide and support effective adaptation by individuals and communities by ensuring that all adaptation efforts are part of a holistic national programme and would be sustainable.

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APPENDICES

Appendix A: Climatic Data for the Ahata West District from 1970-2012

							Monthly Rainfall (mm)						
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Mean rainfall**
1970	115.6	212.9	124.5	167.9	302.5	419.3	45.2	23.6	36.6	260.6	151.9	12.7	156
1971	8.6	129.3	141.5	124.5	149.4	713.9	227.3	48.3	37.9	33.0	112.0	76.2	150
1972	2.8	84.3	228.6	220.7	380.5	198.9	348.7	20.1	81.0	161.5	132.8	82.0	162
1973	36.8	97.8	119.1	177.5	145.3	638.5	35.1	159.5	35.6	255.0	51.3	107.4	155
1974	3.8	63.3	173.5	51.8	321.3	1190.2	464.8	26.9	172.5	129.8	68.6	95.8	230
1975	15.7	71.6	155.7	75.4	259.8	631.9	441.2	31.7	18.5	67.6	130.8	67.1	164
1976	7.6	114.8	195.8	330.0	539.0	532.0	28.2	72.6	2.4	55.3	182.6	114.3	181
1977	25.8	12.0	165.6	163.6	204.3	297.8	7.2	5.9	34.0	106.0	141.6	37.1	100
1978	25.0	153.4	100.7	372.8	805.6	398.2	57.0	47.6	53.2	173.5	76.7	21.5	190
1979	36.8	38.9	100.1	363.5	437.3	542.6	294.7	99.6	198.1	442.7	271.0	125.5	246
1980	82.8	33.8	152.2	169.7	562.2	324.1	188.5	40.6	95.0	279.4	161.9	44.6	178
1981	0.3	17.0	117.4	135.1	465.9	517.5	77.4	23.6	111.9	74.3	74.9	96.7	143
1982	32.0	46.5	60.3	296.1	614.6	573.6	302.1	27.3	12.1	206.2	62.3	25.8	188
1983	0.0	0.8	29.8	50.1	471.7	236.0	33.2	21.1	94.6	114.8		13.3	97
1984	36.4	39.4	73.5	274.1	302.8	717.2	106.3	66.7	49.8	250.9	67.9	0.0	165
1985	15.8	83.6	183.6	50.4	429.5	497.7	116.4	116.4	51.7	79.5	199.0	9.2	153
1986	0.0	55.7	125.3	147.6	224.8	807.3	304.7	7.0	100.2	162.5	117.9	4.1	171
1987	79.1	1.6	184.4	45.4	376.2	375.1	174.5	460.7	465.8	387.7	118.4	79.2	229
1988	13.5	89.3	187.4	318.0	237.4	344.9	38.9	12.5	210.6	130.3	101.3	104.8	149
1989	2.0	14.3	92.5	136.3	274.3	514.5	51.8	133.0	52.9	206.3	39.7	16.2	128
1990	24.9	42.7	12.0	122.5	248.3	309.7	54.8	17.6	48.5	141.4	113.8	248.9	115
1991	80.7	52.7	56.7	149.0	282.5	373.9	423.6	160.2	34.8	87.2	54.2	12.8	147
1992	14.5	0.0	41.1	130.4	465.4	438.5	93.8	4.2	107.6	343.0	142.0	67.1	154

1993	28.3	35.1	131.4	274.2	111.7	891.5	23.5	25.8	63.6	471.6	225.7	72.8	196
1994	123.3	37.5	59.8	254.9	202.8	613.7	48.6	51.1	145.6	461.8	267.9	51.8	193
1995	19.8	37.2	114.5	189.2	270.5	398.6	196.0	44.2	44.0	80.8	243.4	25.0	139
1996	4.1	28.9	183.7	187.8	333.6	492.2	463.3	92.9	53.1	83.0	204.2	34.5	180
1997	14.8	49.9	92.8	147.9	494.4	822.9	34.3	18.0	22.5	191.7	87.4	54.7	169
1998	46.9	5.9	47.3	70.1	89.4	223.6	19.4	30.5	41.5	312.1	152.2	130.3	97
1999	51.6	50.1	95.6	145.5	221.8	538.2	244.5	49.5	33.1	189.0	149.2	117.9	157
2000	49.2	12.5	42.9	148.1	395.7	422.4	89.2	51.5	30.9	58.9	16.7	107.0	119
2001	0.0	38.7	212.3	142.8	413.7	343.4	273.0	30.5	45.7	133.5	195.2	33.7	155
2002	130.3	46.9	43.2	157.2	159.0	482.5	530.8	278.6	18.3	252.4	164.2	47.1	193
2003	63.9	65.5	183.2	380.1	264.4	428.1	85.1	17.8	61.9	237.0	192.2	20.2	167
2004	89.8	110.0	30.5	71.8	137.3	345.7	239.7	22.9	222.9	229.4	183.7	135.9	152
2005	69.3	90.0	193.9	271.5	518.8	290.8	23.5	15.8	74.8	297.3	87.2	48.0	165
2006	0.3	2.3	47.8	92.7	232.7	382.7	95.6	17.5	89.3	195.4	153.7	97.8	117
2007	2.2	55.8	43.5	124.9	125.4	929.2	492.9	72.0	95.6	268.0	44.8	76.9	194
2008	3.9	48.0	89.8	129.2	356.6	375.7	140.0	17.3	118.5	97.2	163.1	26.8	131
2009	41.2	11.8	20.8	121.7	329.8	599.7	402.0	17.3	11.4	41.3	101.3	42.6	145
2010	94.0		128.7	270.0	428.4	463.2	54.3	57.8	120.5	378.4	293.7	179.0	224
2011	14.2	109.6	73.7	75.5	306.9	640.6	95.6	105.7	76.4	462.9	127.2	27.2	176
2012	40.9	35.2	24.6	69.9	429.3	333.8	102.8	32.2	66.8	239.4	127.2	94.0	133
													mean=162

(Appendix A continued)

						Monthly Max. Temp (^{0}C)						
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
29.7	30.3	30.7	30.9	29.9	28.0	26.9	26.2	26.8	28.6	29.6	29.9	979
29.6	29.8	30.0	30.3	30.1	28.1	27.6	26.3	26.6	28.0	29.3	29.2	971
29.6	30.2	30.3	30.1	29.4	28.4	26.7	25.6	26.4	28.3	29.5	30.1	971
30.1	31.2	31.0	31.1	30.1	28.4	27.9	27.0	27.5	28.8	30.4	29.8	995
29.8	30.3	30.3	30.7	29.8	28.2	27.6	27.3	26.8	28.1	29.6	29.3	980
30.0	30.4	30.4	30.5	29.7	28.5	27.2	26.1	26.9	28.1	29.2	29.7	977
29.2	29.5	30.6	30.3	29.3	27.3	26.5	25.9	26.5	27.2	28.9	29.3	959
29.1	30.4	30.9	30.9	29.9	27.9	27.3	26.4	27.8	28.8	30.3	29.9	985
30.2	30.4	30.5	30.0	29.8	28.0	27.2	26.7	27.3	28.0	29.6	30.1	980
30.6	30.5	31.1	31.1	30.0	28.4	27.2	27.6	28.0	28.6	30.0	30.3	995
29.9	30.3	31.0	31.1	29.5	28.5	27.2	27.4	27.9	28.4	29.6	29.9	988
29.8	31.0	31.1	31.4	29.6	28.8	27.3	27.8	28.1	29.6	31.0	30.9	1004
30.9	31.0	31.8	31.2	29.5	29.5	27.3	26.3	27.1	28.1	29.7	30.1	993
31.1	31.5	31.8	31.7		27.7			27.5	29.2		30.0	1016
30.4	31.5	31.4	31.1	30.4			27.2	28.1	28.8	30.3	30.6	1013
29.7												1004
	30.3	30.5	31.2	30.4	28.1	26.7	26.7	27.5	28.3	29.2	29.9	980
29.9	30.3	30.9	31.9	30.7	28.5	27.4	27.4	27.6	28.8	30.9	30.5	999
30.6	31.8	31.1	30.9	30.6	28.5	28.1	27.5	27.7	29.2	30.5	29.9	1004
30.3	31.5	31.1	31.5	30.6	28.7	28.3	27.7	27.4	29.2	31.0	30.8	1009
30.2	30.2	32.2	31.3	30.2	28.8	26.9	26.0	27.5	29.3	30.6	30.1	995
30.5	30.7	31.1	30.4	29.9	29.1	27.8	26.8	27.4	27.8	29.5	30.0	989
30.6	31.3	30.9	31.0	29.7	27.9	26.4	26.6	27.2	28.5	29.4	30.3	985

30.2	31.0	30.4	30.7	30.3	28.1	27.3	26.7	28.3	29.5	30.6	30.5	996
30.1	31.2	31.5	31.1	29.9	28.3	27.1	26.7	26.9	28.0	30.0	30.7	990
30.2	31.4	31.0	31.6	30.7	29.2	28.2	27.7	27.8	29.1	30.5	30.7	1009
30.3	31.0	31.1	31.3	30.6	28.4	27.8	26.8	27.2	28.7	29.9	29.8	994
30.0	31.1	30.7	30.5	29.7	27.9	27.4	27.0	28.3	29.9	30.9	31.2	999
31.2	32.5	32.8	32.2	31.1	29.3	28.1	27.3	28.2	29.0	31.0	30.9	1024
30.4	30.8	31.2	30.8	30.5	29.4	28.1	27.4	27.1	28.0	30.0	30.5	998
29.7	30.8	31.2	30.8	30.5	28.3	27.5	26.9	27.2	28.4	30.7	30.0	991
29.4	31.3	31.1	30.7	30.3	28.5	27.1	26.4	26.9	29.0	30.1	30.4	989
30.1	30.9	30.9	30.8	30.8	28.2	26.7	26.8	27.1	28.8	30.4	30.5	991
30.1	30.9	31.7	30.8	30.5	28.3	27.8	27.0	28.0	29.4	30.8	30.8	1003
30.5	31.3	32.1	31.1	30.2	27.9	27.1	26.5	27.7	29.1	30.6	30.6	999
30.0	31.3	31.3	31.4	29.8	28.2	27.1	26.7	27.9	29.6	30.9	30.7	1000
30.2	30.8	31.7	31.7	30.0	29.5	27.9	27.6	27.5	29.4	30.6	30.6	1007
30.5	30.9	31.5	31.2	30.9	28.4	28.0	27.4	27.7	28.8	30.6	31.1	1006
30.5	31.9	31.1	31.3	30.7	29.3	28.6	28.3	27.8	29.4	30.8	31.2	1017
30.7	31.3	31.4	31.2	30.9	29.4	27.9	27.0	27.6	28.5	30.2	31.1	1006
30.7		32.1	32.0	31.3	29.1	28.3	27.9	28.2	29.1	30.2	31.3	1015
30.7	30.8	31.5	31.7	30.9	29.1	28.1	26.9	27.8	28.8	31.1	30.9	1009
30.7	29.9	31.6	30.8	30.1	28.6	27.7	27.0	27.7	29.0	31.1	31.1	1001

APPENDIX B: Vulnerability of Community Assets and Livelihoods to Climate Change and Variability

QUESTIONNAIRE (Community members)

University of Cape Coast

Department of Fisheries and Aquatic Sciences

Target group(s): Chiefs, Fishermen, Farmers, Fish mongers, traders, youth etc

QUESTIONNAIRE ON CLIMATE CHANGE VULNERABILITY AND ADAPTATION PLANNING IN AKWIDAA, AHANTA WEST DISTRICT, WESTERN REGION

This questionnaire is to enable a researcher at the Department of Fisheries and Aquatic Sciences of the University of Cape Coast, gather information on how vulnerable the Akwidaa community is to climate change. Please provide in-depth responses to the questions below since it will help the researcher propose measures for effective adaptation planning in the community.

Tick the appropriate option(s)

SECTION B: IDENTIFICATION OF CLIMATE AND NON-CLIMATE CHANGE PHENOMENA

Please tick the appropriate option.

1. Indicate the climate change phenomena that have impacted the community in the past as well as expected impact(s) to your community.

Climate change phenomena	**Past**			**Future**		
	Strongly agree	**Agree**	**Disagree**	**Strongly agree**	**Agree**	**Disagree**
(a) Rising sea level						
(b) Increasing storm intensity						
(c) Changing precipitation pattern						
(d) Increasing air temperature						
(e) Increasing water temperature						

2. Indicate the non-climate change phenomena (human induced factors) that have impacted the community in the past as well as expected impact(s) to your community.

Non-Climate change phenomena	Past			Future		
	Strongly agree	**Agree**	**Disagree**	**Strongly agree**	**Agree**	**Disagree**
(a) Mangrove cutting						
(b) Sand winning						
c)Charcoal burning						
(e) Deforestation						
(f) Others						

SECTION C: IDENTIFICATION OF CLIMATE CHANGE IMPACTS AND CONSEQUENCES

Target group(s)……………………………………

Please indicate the appropriate option.

3. Climate change impacts and consequences are the changes to the physical, economic, social and natural systems that occur as a result of climate change phenomena. What is the level of impact of the climatic factors on the community assets? (Please indicate as Very high =1; High = 2; Medium = 3; Low = 4 or Not applicable = 5).

Community assets	**Impacts resulting from climate change phenomena**			
	Coastal erosion (Rising sea level)	Floods (Changing precipitation pattern)	Droughts (Increasing air temperature)	Others
Houses				
Clinic				
Markets				
Bridges				
Schools				
Roads				
Toilets				
Pipe water				

4. What is the level of impact of the non-climatic factors on the community assets?

(Please indicate as Very high=1; High = 2; Medium = 3; Low = 4 or Not applicable)

Community assets		Impacts resulting from Non-climate change phenomena		
		Mangrove cutting	Sand Winning	Charcoal burning
Built environment	Houses			
	Clinics			
	Markets			
	Bridges			
	Schools			
	Roads			
	Toilets			
	Pipe water			

SECTION C: ASSESSMENT OF ADAPTIVE CAPACITIES

Target group(s)…………………………… ………

Please indicate the appropriate option.

The vulnerability of a coastal area to climate change will depend not only on the physical stressors to the environment but also on the ability of the affected areas to adapt to those changes referred to as "Adaptive capacity" *Please tick Yes= 1, No=2*

10 a) What are the regulatory and planning capabilities?

Existing regulatory and planning capabilities		Impacts resulting from climate change phenomena		
		Coastal erosion (Rising sea level)	Floods (Changing precipitation pattern)	Droughts (Increasing air temperature)
Regulatory and planning capabilities	Building codes			
	Development restrictions			
	Coastal management regulations			

	Shoreline management			
	Land use planning			

(a)What are the administrative and technical capabilities

Administrative and technical capabilities		**Impacts resulting from climate change phenomena**		
		Coastal erosion (Rising sea level)	Floods (Changing precipitation pattern)	Droughts (Increasing air temperature)
Administrative and technical capabilities	Dedicated staff			
	Climate change experts			
	Engineers NADMO			
	GIS & Modeling resources			
	EPA			
	TCP			

(c) What are the fiscal capabilities?

Fiscal capabilities		**Impacts resulting from climate change phenomena**		
		Coastal erosion (Rising sea level)	Floods (Changing precipitation pattern)	Droughts (Increasing air temperature
	Grants			
	insurance			
	Loans			
	Development levy			

1. What are the capabilities related to infrastructure protection?

Capabilities relative to protection of infrastructure		**Impacts resulting from climate change phenomena**		
		Coastal erosion (Rising sea level)	Floods (Changing precipitation pattern)	Droughts (Increasing air temperature)
Infrastructure protection	Flood and erosion control structures			
	Evacuation routes			
	Boulders along the beaches			
	Damping of refuse along the beach			
Others				

(Appendix B continued)

Date…………………………….. Serial number……

QUESTIONNAIRE ON CLIMATE CHANGE VULNERABILITY AND ADAPTATION PLANNING IN AKWIDAA IN THE AHANTA WEST DISTRICT, WESTERN REGION

SECTION A: FISHERIES BASED ACTIVITIES

Please provide the appropriate answers

IDENTIFICATION OF CLIMATE CHANGE IMPACTS AND CONSEQUENCES

Target group(s): Fishermen

Please indicate the appropriate option. Climate change impacts and consequences are the changes to the physical, economic, social and natural systems that occur as a result of climate change phenomena. What is the level of impact of the climatic factors on the community assets? (Please indicate as High = 1; Medium = 2; Low = 3; Very low = 4 and Not applicable = 5).

1. What is the level of impacts of climatic factors on the fishing activities?

	Impacts resulting from climate change phenomena

Fisheries based activities			
		Floods (Changing precipitation pattern) /How	Droughts (Increasing air temperature)/How
Fishing activities	Fish landings		
	Fish trading		
	Aquaculture		
	Boat building		
	Fish processing (smoking, frying etc)		
	Others (Specify)		

SECTION B: NON-FISHERY BASED ACTIVITY

Target groups: Farmers and traders

Please indicate the appropriate option. Climate change impacts and consequences are the changes to the physical, economic, social and natural systems that occur as a result of climate change phenomena. What is the level of impact of the climatic factors on the community assets? (Please indicate as High = 1; Medium = 2; Low = 3 or Not applicable = 4).

1. What is the level of impacts of climatic factors on the fishing activist

Non-Fisheries based activities		**Impacts resulting from climate change phenomena**	
		Floods (Changing precipitation pattern) / How	Droughts (Increasing air temperature)/ How
Non-fisheries based activities	Farming		
	Petty trading		
	Animal farming		
	Casual work		
	Leasing out of		

	land		
	Small scale business		
	Others (Specify)		