UNIVERSITY OF GHANA

CONSERVED FORESTS AND SUSTAINABLE LIVELIHOODS IN THE FACE OF CLIMATE CHANGE: EXPERIENCES OF FRINGE COMMUNITIES ALONG THE ATIWA RANGE FOREST RESERVE

BY

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DECLARATION

This is to certify that this thesis is the result of research undertaken by Apeanti Timothy under the supervision of Dr. Rosina Kyerematen, and Dr. Erasmus Owusu, towards the award of the Master of Philosophy degree in Climate Change and Sustainable Development, University of Ghana, Legon.

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DEDICATION

This work is dedicated to my parents Mr. and Mrs. Oduro of Akyem Akropong for their care, advice and guidance in my life

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LIST OF ABBREVIATIONS

AfDB	African Development Bank
AGU	American Geophysical Union
AMCEN	African Ministerial Council on the Environment
ARFR	Atiwa Range Forest Reserve
CBD	Secretariat of the Convention on Biological Diversity
COMIFAC	Treaty on the Conservation and Sustainable Management of Forest Ecosystems in Central Africa and to Establish the Central African Forests Commission
ECOWAS	Economic Community of West African States
ESS	Ecosystem Services
FAO	Food and Agriculture Organization
FGDs	Focus Group Discussions
FRAP	Food and Agriculture Organisation's Forest Resource Assessment Programme
GHGs	Greenhouse Gases
GMet	Ghana Meteorological Agency
GSS	Ghana Statistical Service
IBA	Important Bird Area
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
MDG	Millennium Development Goals
MA	Millennium Ecosystem Assessment Report

NOAA	National Oceanic and Atmospheric Administration
NASA	the National Aeronautics and Space Administration
NGOs	Non-Governmental Organisations
NTFPs	Non-timber Forest Products
RS	Remote Sensing
UNFCCC	United Nations Framework Convention on Climate Change
UNCCD	United Nations Conference to Combat Desertification
UNEP	United Nations Environment Programme
UEF	Upland Evergreen Forest
WRI	Water Resource Institute

ABSTRACT

The climate change challenge in this century threatens life itself on the planet; natural systems and human societies alike. The ability for human systems to adjust to and deal with threats posed by climate change is in no doubt better than natural systems. The very existence and well-being of humanity especially the rural poor is solely dependent on a proper functioning natural systems and the services they provide and more importantly the livelihoods they derive from it. This study was primarily to assess the effects of climate change on ecosystem services provided by the Atiwa Range Forest Reserve and its effects on livelihood outcomes on fringe communities along the reserve. In carrying out the work, the mixed method of social science research approach was used; 184 respondents were randomly surveyed from three communities along the range whilst 44 respondents were purposively selected for in-depth interviews and Focus Group Discussions. The results from the survey were analysed using three statistical tests: the Pearson Chi-square, McNemar-Bowker Chi-square and binary logistics regression. Respondents' perception on variable rainfall and a rising temperature in the area was corroborated by the scientific data obtained from the Ghana Meteorological Agency. It was also found that as amount of rainfall decreases, forest productivity also decreases leading to respondents' widely held observation that both ecosystem services and livelihood outcomes have reduced relative to the past. It was recommended that for the forest to continue performing its role in supporting these poor communities, the people should be actively involved in forest protection.

CHAPTER ONE

GENERAL INTRODUCTION

1.1 Background to the study

Natural ecosystems benefit people in many ways, from regulating local climates to providing clean drinking water. The benefits supplied by ecosystems are collectively referred to as ecosystem services. While these services provide the basis for the livelihoods of many societies and play an important role in ensuring food, water and energy security, they are also fundamental tools in dealing with climate change (Travers *et al.*, 2012). The forest ecosystem offers myriad of opportunities for climate change mitigation and adaptation at a low cost and more importantly poverty alleviation at the community, national and global levels of the developmental agenda.

As far as climate change is concerned, the United Nations Framework Convention on Climate Change (UNFCCC) articulates two approaches for addressing the phenomenon: mitigation (that is, reducing emissions and increasing carbon sequestration) and adaptation (adjusting to the already changing climate while taking advantage of opportunities). Forestry activities are key options for both adaptation to and mitigation of climate change… and that forest projects constitute a least-cost option to reducing emissions, to sequestering additional carbon, and to increasing the adaptive capacity of local people (Robledo, et *al*., 2008).

There is increased attention to reducing emissions from deforestation as a low cost mitigation option, and with significant positive side-effects (Stern, 2006). Nabuurs *et al*.

(2007) have also noted that forestry can make a very significant contribution to a low-cost global mitigation portfolio that provides synergies with adaptation and sustainable development. In addition, forests play a key role in biogeochemical cycles critical among which is the world carbon cycle (WRI, 2000) and the hydrological cycle.

Forests provide socio-cultural and economic benefits to society as well. These include timber and non-timber products sector employment, energy, education, recreation and tourism. The production of forest products further, provides many opportunities for income generation and employment in rural areas. Activities include timber production, sawmilling operations, collection of forest materials for making handicrafts and furniture, and charcoal production (www.forestry.gov.jm/). Forests also provide raw materials for food, fuel, and shelter.

Besides these tangibles, the forest ecosystems also provide numerous intangibles for human well-being. In forests, ecosystem components such as micro-organisms, soils and vegetative cover interact to purify air and water, regulate the climate and recycle nutrients and wastes. Without these and many other ecosystem goods and services, life as we know it would not be possible (Krieger, 2001).

Many aspects of the stability, functioning, and sustainability of global ecosystems depend on the diversity of plant and animal species (Tillman, 1997) and the world's biodiversity functions as a ''genetic library'' that supports important human welfare functions such as the improvement of existing crops, introduction of new crops, and the creation of medicines and pharmaceuticals (Myers, 1997). Forest ecosystems in tropical Africa are important repositories for vital livelihood resources and ecosystem services, and, at the same time, constitute major wildlife habitats including corridors that allow for migration facilitating coping with climate risks.

The biodiversity of tropical forests in Africa is being threatened by a range of human activities such as mining, habitat loss due to conversion to agricultural land and logging, over-exploitation for fuel wood, food, medicinal plants, overgrazing, water catchment and river channel destructions some of which are in response to climate change pressures (Nkem *et al.*, 2008).

Forest reserves in Ghana are increasingly under threats of exploitation for a wide range of resources; trees, animals, and mineral deposits. Atiwa Range Forest Reserve (ARFR) in the Eastern Region is under persistent threat for its resources, and future uncertainties of the climate make fringe communities in the area increasingly vulnerable. It is one of the largest remaining blocks of tropical forest in West Africa which assumes a great role on the landscape as repository of variety of plants and animals and water bodies of global and national importance. The reserve holds not only the headwaters of three important rivers in Ghana; Densu, Birim and Ayensu which supply over 5 million people with water in Accra and its environs but also has biodiversity of global significance (www.arocha.org). ARFR is unique because it is one of only two Upland Evergreen forests in Ghana the other being the Tano-Ofin Forest Reserve, which is much smaller and significantly more disturbed. Any changes which negatively affect the proper functioning of the reserve should be a cause for concern and there is the need for more research and policy attention (McCullough *et al*, 2007).

This work is focused on assessing the effect of climate change on ecosystem goods and services of the reserve and the livelihoods derived from the reserve by fringe communities. More specifically, it focused on how ecosystem goods and services generated by the forest have been affected by the climate variability in the area.

1.2 Problem statement

All forests contain environmental, economic and social values, such as wildlife habitat, watershed protection or archaeological sites (Jennings *et al*, 2003). Forests are sources of timber and paper products, recreational facilities as well as a sink for carbon dioxide thereby reducing global warming (Myers, *et al*, 2000). The way forests are now utilized must thus be carefully balanced in a manner that will enable it withstand both internal and external shocks for future generation to derive the same benefits as now, if not better.

This is however not the case. There are constant threats to forests as ecosystems currently from various external stressors especially since the last century where human population boom has put natural resources under critical constraint. Principal among these stressors are agriculture, settlements, industrialization, mining and climate change. Land-use patterns associated with urban, suburban, rural, and agricultural development very likely complicate ecosystem adaptation to climate change by hindering migration (Higgins & Harte, 2006).

According to Sunderlin *et al.,* (2005), the Earth's vegetation cover has been vanishing. In the course of the last 8,000 years, the earth's forest cover has been reduced by almost half from 62 million km^2 to 33 million km^2, and much of this loss has occurred in the last three decades (Bryant, *et al.,* 1997). Between 1990 and 1997, 5.8 ± 1.4 million ha of humid tropical forests were lost each year, and 2.3 ± 0.7 million ha of forests degraded (Achard *et al.,* 2002). The main threat to neo-tropical biodiversity is the persisting high rates of deforestation and forest degradation (CBD, 2001a). For example in South America 3.7 million ha of tropical forests are lost every year (FAO, 2000), while in Central America the forests lost between 1990 and 1995 is estimated at 2.5% annually (FAO 1996; 1997a; Guevara & Villamizar 2001).

The large-scale forest loss aggravates climate change by contributing to greenhouse gas (GHG) emissions. For instance, the carbon dioxide (CO_2) stored by Africa's forests alone is estimated at 60 billion tons (Unmusig and Cramer, 2008). Africa's relatively high rates of forest loss in the 12 most densely wooded countries in the region accounted for 1.1 billion tons of CO_2 in 2005 (FAO, 2007b; UNDP, 2007). Africa's humid forests, particularly in western and central Africa, have particularly high concentrations of carbon stocks, taking into account carbon in the soil, litter, and dead wood. While dry forests have less carbon, they account for around 42 percent of tropical forest area in Africa, and are therefore an important element of any policy linked to forests and climate change (Murphy & Lugo, 1986; Murdiyarso *et al*., 2008). Forest destruction therefore reduces the economic growth from natural resources (Dempsey & Robertson, 2012) through reduction in ecosystem services and livelihoods poor communities derive.

Despite Africa's fast-growing human population and the associated impacts on natural resources, it is one of the least studied continents in terms of ecosystem dynamics and climate variability (Hély *et al*., 2006). Climate change however, is already having an impact on the dynamics of African biomes and its rich biodiversity, although species composition and diversity is expected to change due to individual species response to climate change conditions (Erasmus *et al*, 2002).

These concerns are linked to the concept of vulnerability; defined as a high degree of exposure to risk, shocks and stress and proneness to food insecurity (Chambers, 1989: Davies, 1996). Tropical forests provide livelihood opportunities for over 1.6 billion people worldwide living in extreme poverty (UNCCD *et al.,* 2004). They also provide an indispensable asset for contributing to national poverty reduction strategies and, consequently, the realization of some of the millennium development goals (MDG 1 and 7) in developing countries.

Like any renewable resource, forests self-generate and could potentially provide a flow of benefits in perpetuity. However, immediate and pressing socio-economic needs of many poor communities present a challenge to sustainable forest management (AfDB, 2013). Recent studies have drawn attention to the enormous diversity in rural livelihood strategies – within geographic areas, across sectors, within households and over time. Households combine activities to meet their various needs at different times. The more choices and flexibility people have in their livelihood strategies the more secure they are and the more able to cope with 'shocks' (Turton, 2000).

Ghana is rich in forest resources and one that particularly interest research and policy makers is the Atiwa Range Forest Reserve (ARFR) in the Eastern Region. Over the last 90 years, ARFR has been recognized as an important reservoir of biodiversity and has been officially classified in various ways: as a national forest reserve in 1926, a Special Biological Protection Area in 1994, a Hill Sanctuary in 1995 and as one of Ghana's 30 Globally Significant Biodiversity Areas (GSBAs) in 1999. In 2001, it was listed as an Important Bird Area (IBA) by BirdLife International. The value of Atiwa lies not only in the presence of rare or threatened species within its forest and the clean water produced by the watershed, but also in being a unique and a very complex ecosystem, one with a combination of species found nowhere else on the planet (McCullough *et al*, 2007). The livelihoods fringe communities derived from the forest are also key for the survival of the people and the economy of the area.

In recent years however, this all important reserve has been significantly disturbed by human activities like mining, illegal logging, agricultural activities, illegal hunting, that threaten not just the special resources such as water bodies and favorable soil but has put serious constraint on both rare and threatened species the reserve has harbor for all these years. As the resources in the reserve get depleted through constant human activities, it puts the ecosystem in great danger which then negatively affects livelihood outcomes in the area.

1.3 Aim and Objectives

The general objective of the study was to assess the effect of climate change on ecosystem goods and services provided by the Atiwa Range Forest Reserve and its effects on livelihood outcomes in fringe communities along the reserve.

In an attempt to achieve the broader objective above, the study was guided by the following specific objectives:

- to identify the key ecosystem services provided by the reserve
- to investigate livelihoods options fringe communities derive from the reserve.
- to assess the relationship between climate change effects on ecosystem services and livelihood outcomes in fringe communities along the reserve.
- to find out key adaptation strategies communities are adopting to reduce vulnerability against adverse impact of the continuous depletion of forest and the long term climate change consequence.

1.4 Rationale for the study

The significance of the study would be ascertained in terms of its contribution to research, practice and policy. Specifically, the study would serve these purposes:

- It would bring to bear the effect of climate change on the benefits communities derived from the Atiwa forest.
- It also would bring out the main factors combining to reduce forest productivity in developing countries in general and the study area in particular.

- Key alternative livelihood options in the area, the organisations spearheading these programmes and the challenges confronting these organisations would also be brought to bear.

CHAPTER TWO

LITERATURE REVIEW

2.1 Climate Change: The Phenomenon and the Controversy

Both the United Nations Framework Convention on Climate Change (UNFCCC) and the Intergovernmental Panel on Climate Change (IPCC) the foremost international bodies spearheading the climate change agenda attribute the causes of current climate change to a 'discernible human action' (IPCC, 2007 and 2014) in their respective definitions of the concept. The IPCC defines climate change as 'a change in the state of the climate that can be identified (for example, by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. According to this international body of experts, climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use' (IPCC, 2014).

The UNFCCC definition of climate change emphasizes anthropogenic causes and subtly mentions natural causes of the phenomenon. Thus it defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods." The UNFCCC thus, makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes (IPCC, 2014).

These definitions by the two bodies seem to have ruffle feathers among the scientific community. There has been incessant attack on these definitions by some climate change denials and critics. For instance, Pielke (2005) concerned about a likely international dogma in tackling adaptation, has argued that the UNFCCC's definition has brought about conflict between science, politicians and policy makers and that it has contributed to the gridlock and ineffectiveness of the global response to the challenge of climate change. He argued that the consequences of misdefining ''climate change'' create a bias against adaptation policies and set the stage for the politicization of climate science. He went on to argue on a basis for a common ground for science, policy and politics to achieve effective adaptation. He then rooted for the more technical and a well-crafted definition by the IPCC.

However, Carter (2006) criticizes the IPCC definition by saying that, because the Framework Convention (UNFCC) defines 'climate change' as that change which is due to human activity, it is clear that from the outset, the IPCC's role has been to concentrate on presumed anthropogenic change rather than to comment on or prepare for natural variations in the climate system itself or prepare for both. Accordingly, it has led to governments, businesses, the media and environmental activists all assuming that IPCC reports have provided conclusive evidence that human emissions of greenhouse gases are warming the climate.

However climate change is viewed, there is little doubt and overwhelming consensus among the scientific community that, even though climate change may have its natural cause through events like suns' activities, volcanic eruption, El-Nino effect (ISDR, 2008), the current warming has been precipitated by human impact on the earth's climate system. For instance, according to Pittock (2006) there is increasing evidence that the rapid warming which is occurring around the globe is due mostly to human induced changes in the atmosphere, which have been superimposed over natural variations. Moreover, the difference between the current warming to those of the distant past when humans had little or no control over the landscape is that global temperatures have risen unusually rapidly over the last few decades. There is strong evidence of increases in average global air and ocean temperatures, widespread melting of snow and ice, and rising average global sea levels (ISDR, 2008).

Hegerl, *et al.*, (2007) have observed that human-induced warming of the climate system is widespread. Anthropogenic warming of the climate system can be detected in temperature observations taken at the surface, in the troposphere and in the oceans. They further state that, multi-signal detection and attribution analyses, which quantify the contributions of different natural and anthropogenic forcings to observed changes, show that greenhouse gas forcing alone during the past half century would likely have resulted in greater than the observed warming if there had not been an offsetting cooling effect from aerosol and other forcings.

The National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), the United Kingdom Meteorological Office's Hadley Centre and the Japanese Meteorological Agency agree that 2010 and 1998 were the hottest of the 10 hottest years on record with 13 of the warmest years having occurred between

1997 and 2011. These data and findings for 2010 add weight to the common conclusion of all four agencies and most of the scientific community, that in spite of short-term spatial and temporal variability the clear long-term trend is one of global warming (AMCEN, 2011).

According to Case (2006), climate change is real and happening now. The average global surface temperature has warmed 0.8°C in the past century and 0.6°C in the past three decades (Hansen *et al.*, 2006), in large part because of human activities (IPCC, 2001). A recent report produced by the U.S. National Academy of Sciences confirms that the last few decades of the 20th century were in fact the warmest in the past 400 years (National Research Council, 2006). The Intergovernmental Panel on Climate Change (IPCC) also projected that if greenhouse gas emissions, the leading cause of climate change, continue to rise, the mean global temperatures will increase 1.4 – 5.8°C by the end of the 21st century (IPCC, 2001).

A broad range of GHG emissions scenarios are now considered possible for the next century (Nakicenovic *et al.*, 2000), leading to a range in expected globally averaged temperature increases of 1.4°C to 5.8°C by the year 2100 as earlier stated (IPCC 2001). At the low end of the range of projected GHG emissions, such as the B1 scenario (www.grida.no/climate/ipcc_tar/wg1/008.htm), atmospheric carbon dioxide (CO2) would increase to roughly 550 parts per million (ppm) by 2100, relative to roughly 280 ppm under preindustrial conditions(IPCC 2001). The increase in radiative forcing associated with GHG concentrations under the B1 scenario is roughly 4.2 watts (W) per m^2, which leads to predicted increases in globally averaged annual temperature toward the lower end of the expected range (www.ipcc.ch/pub/taroldest/wg3/015.htm). At the high end of the GHG emissions scenarios, the A1FI scenario would lead to CO_2 concentrations of roughly 1000 ppm by 2100. This translates into an increase of roughly 9.1 W per m^2 in globally averaged radiative forcing, and predicted temperature increases at the high end of the expected range (www.ipcc.ch/pub/taroldest/wg3/015.htm).

According to the IPCC (2014), changes in climate have caused impacts on natural and human systems on all continents and across the oceans with impacts strongest and most comprehensive for natural systems. Some impacts on human systems have also been attributed to climate change, with a major or minor contribution of climate change distinguishable from other influences. The report further states that, many terrestrial, freshwater, and marine species have shifted their geographic ranges, seasonal activities, migration patterns, abundances, and species interactions in response to ongoing changes in climatic system.

One region of the world where the effects of climate change are being felt particularly hard is Africa. As a result, of the lack of economic, development, and institutional capacity, African countries are likely among the most vulnerable to the impacts of climate change (IPCC, 2001). Climate change impacts have the potential to undermine and even, undo progress made in improving the socio-economic well-being of all parts of Africa. The negative impacts associated with climate change are also compounded by many factors, including widespread poverty, human diseases, and high population density, which is estimated to double the demand for food, water, and livestock forage within the next 30 years (Davidson *et al*. 2003).

The foreword of Addressing Climate Change Challenges in Africa: A practical Guide Toward Sustainable Development, the Chairperson of African Ministerial Council on the Environment (AMCEN) and Malian Minister for Environment wrote, there is a consensus among scientists, policy makers and development practitioners that climate change poses complex challenges to the development of countries in Africa. He went on to say that, recent scientific information since the Inter-governmental Panel on Climate Change (IPCC) 4th Assessment Report confirms the world is on course for levels of warming that will be catastrophic for Africa (AMCEN, 2011).

Average annual temperatures in Africa rose steadily in the 20th century; in some parts of African, for example, the rate of warming was approximately 0.7°C and the six warmest years all occurred after 1980. On average, temperature increases are projected to be higher in Africa than they will be globally, with warming greatest in drier, sub-tropical regions. Climate models project a median temperature increase of 3–4°C across the continent by the end of the current century, which would be approximately 1.5 times the global average increase (Kleine *et al*., 2009).

Africa experiences a wide variety of climate regimes, in which its location, size, and shape play key roles. Rainfall amount, duration and seasonality are the most important factors in differentiating the African climate regimes, which vary from the Indian Ocean to Central

Africa and from the North to the South, ranging from humid equatorial regimes, through seasonally-arid tropical regimes, to sub-tropical Mediterranean-type climate (Hulme *et al.*, 2001).

The United Nations Environment Programme (UNEP) Emission Gap Report confirms that the current mitigation pledges – unless strengthened – will set the world on course for global warming of between 2.5 to 5°C. Further to this, there is indication that temperature rises are likely to be progressively higher in Africa with other climate related effects such as variability in precipitation patterns and the frequency of extreme weather events placing considerable pressure on livelihoods and economies across the continent (AMCEN, 2011).

Available temperature data indicates a warming climate in Ghana with the drier northern area warming more rapidly than southern Ghana. Since 1960 for Ghana as a whole, mean annual temperature rose by 1.0°C. The rate of increase generally was more rapid in the northern than southern regions. The frequency of “Hot” days and nights in Ghana increased from 1961 to 2003. A “Hot” day or night is defined by the temperature exceeded on 10 percent of days or nights in the current climate. Annual rainfall in Ghana is highly variable making identification of long-term trends difficult. In the 1960s, rainfall in Ghana was particularly high and decreased to particularly low levels in the late 1970s and early 1980s (Stanturf *et al.* 2011).

2.2 Climate Change and Forest Ecosystem

In the scientific arena, it has become accepted that climate change is a reality, with the debate now focused on the magnitude and timing of change, the increasing frequency and intensity of extreme events, as well as on the potential impacts of change on natural and anthropogenic systems, including the forestry sector (Warburton & Schulze, 2006).

According to Case (2006) the effects of climate change such as rising temperature and changes in precipitation are undeniably clear with impacts already affecting ecosystems, biodiversity and people. In both developed and developing countries, climate impacts are reverberating through the economy, from threatening water availability to sea-level rise and extreme weather impacts to coastal regions and tourism. He further states that in some countries, climate impacts affect the ecosystem services that communities are largely dependent upon, threatening development and economic stability. Future impacts are projected to worsen as the temperature continues to rise and as precipitation becomes more unpredictable.

The large and rapid climate changes expected over the next century, even under moderate greenhouse gas (GHG) emissions scenarios (IPCC 2001), would require much faster rates of species migration than those optimistically supposed for postglacial warming (Solomon & Kirilenko 1997, Malcolm *et al.*, 2002). The climate changes expected over the next 100 years exceed those of the past century (IPCC 2001) and are likely to lead to additional range shifts as the narrow climate characteristics required by many individuals, populations, and species move throughout the world (Higgins & Harte, 2006).

A number of researchers have used ecological models to project the extent to which a specific climate change is expected to shift the geographic distribution of plants, particularly tree species (Emanuel *et al.*, 1985; Shugart *et al.*, 1986; Solomon *et al.*, 1996; Neilson & Marks, 1994). Forests have responded to past climate change with alterations in the ranges of important tree species (Shugart *et al.*, 2003), but a critical issue is the rate at which tree species migrate (Sedjo, 2010).

Climate-related damage to forests could include fire, infestation, disease, and windthrow, particularly if the trees are already under stress and thus susceptible to dieback. Extreme events associated with climate change, such as windstorms and wildfire, could put even healthy forests at risk. Some forest-replacing events, however, could facilitate the transition to a newer, better-adapted forest (Sedjo, 1992).

The projected rapid rise in temperature combined with other stresses, such as the destruction of habitats from land use change, could easily disrupt the connectedness among species, transforming existing communities, and showing variable movements of species through ecosystems, which could lead to numerous localized extinctions. If some plant species are not able to respond to climate change, the result could be increased vulnerability of ecosystems to natural and anthropogenic disturbance, resulting in species diversity reductions (Malcolm *et al*., 2002).

Adaptation to climate change could occur naturally, through natural regeneration and tree migration, and could also be facilitated by human action if managers replant disturbed forests in species or varieties more suitable to the changed climate and establish new, replacement plantations in more suitable locations (Sedjo 2010).

Finally, tropical forests have important roles on the landscape but they are currently experiencing rapid deforestation and degradation with signifjicant reduction in forest cover and fragmentation across the landscape (Nkem *et al.*, 2008). For example, over 4 million ha/yr of forest in Africa is estimated to be lost annually since 2000 (FAO, 2005). Carbon emissions resulting from this annual loss in forest and other vegetation are estimated to range from 440 to over 1200 Mt CO_2/yr in sub-Saharan Africa (IPCC, 2007b).

2.3 Forest Resources: Mitigation Tool and Source of Livelihoods

The Food and Agriculture Organisation's Forest Resource Assessment Programme (FRAP, 2010) report defines forest as land spanning more than 0.5 hectares (ha) with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds *in situ*. It does not include land that is predominantly under agricultural or urban land use. This definition means that forest is determined both by the presence of trees and the absence of other predominant land uses and that the trees should be able to reach a minimum height of 5 meters *in situ*.

It also includes areas with young trees that have not yet reached but which are expected to reach a canopy cover of 10 percent and tree height of 5 meters. Moreover, areas that are temporarily unstocked due to clear-cutting as part of a forest management practice or natural disasters, and which are expected to be regenerated within 5 years are also considered a forest. Local conditions may, in exceptional cases, justify that a longer time frame is used (FRAP, 2010). The global forest cover is 3952 million ha, which is about 30 percent of the world's land area (FAO, 2006).

Climate change and forest cover have interesting relationships. Biophysical and biogeochemical characteristics of the land surface affect climate by influencing carbon storage, land-surface albedo, and evapotranspiration (Betts *et al.*, 1997, Lashof *et al.*, 1997, Sellers *et al.*, 1997, Field and Avissar 1998, Pielke *et al.*, 1998, Saleska *et al.*, 2002, Feddema *et al.*, 2005). Results of a research conducted by Higgins and Harte (2006), demonstrate that ecosystem responses to climate change can include important climate feedbacks even if plant migration is extremely fast.

Emissions from land-use change, primarily tropical deforestation and forest degradation, contribute to an estimated 20 per cent of total anthropogenic greenhouse gas emissions (IPCC 2007), even though Rogner *et al.*(2007) estimate forest loss in the tropics to contribute approximately 17 per cent of global greenhouse gas emissions. Based on a five-year study, FAO (2005) found that forest areas throughout the world were declining at a rate of about 7.3 million hectares per year, an area equivalent to Panama and Sierra Leone.

Globally, hundreds of millions of households depend on goods and services provided by forests. This underlines the importance of assessing forest sector activities aimed at mitigating climate change in the broader context of sustainable development and community impact. Forestry mitigation activities can be designed to be compatible with adapting to climate change, maintaining biodiversity, and promoting sustainable development.

Comparing environmental and social co-benefits and costs with the carbon benefit will highlight tradeoffs and synergies, and help promote sustainable development (Nabuurs, *et al.*, 2007).

Forest ecosystems provide a wide range of ecosystem services from which people benefit, and upon which most life forms depends. These include provision of food, fuel, building materials, freshwater, climate regulation, flood control, nutrient and waste management, maintenance of biodiversity, and cultural services, to name a few. The 2005 Millennium Ecosystem Assessment shows that nearly two-thirds of the world's ecosystems are now under threat due to incessant depletion of the earth's forest (Bond *et al.*, 2009).

The 2005 Millennium Ecosystem Assessment reports that 60% of the world's ecosystem services are degraded to the point where they no longer provide sufficient benefits to people (MA, 2005). Moreover, the on-going degradation of ecosystem services is increasing the likelihood of serious damage to human well-being (Peskett *et al.*, 2008).

Tropical forests provide livelihood opportunities for over 1.6 billion people worldwide living in extreme poverty (UNCCD *et al.* 2004). They also provide an indispensable asset for contributing to national poverty reduction strategies and, consequently, the realization of some of the millennium development goals (MDG 1 and 7) in developing countries (Nkem *et al*., 2008).

According to Swanes *et al.*,(1997) close to 40% of pharmaceutical products used in the USA are either based on or synthesized from material compounds found in plants, animals, or microorganisms. Other uses of the forest include the promotion of eco-tourism, with financial benefits to the local citizens (The International Eco-Tourism Society, 1992), aesthetic and cultural benefits (Gormey, 1997), and scientific research. Forests have therefore contributed and continue to contribute to the survival of man (Addai and Baidoo, 2013).

Even though national statistics on forest management plans are not available for many developing countries it is estimated that at least 123 million ha, or about 6% of the total forest area in developing countries is covered by a "formal, nationally approved forest management plan covering a period of at least five years." Proper management plans are seen as prerequisites for the development of management strategies that can also include carbon-related objectives (Nabuur *et al.*, 2007).

Sustainably managed forests have multiple environmental and socio-economic functions which are important at the global, national and local scales, and they play a vital part in sustainable development. Reliable and up-to-date information on the state of forest resources - not only on area and area change, but also on such variables as growing stock, wood and non-wood products, carbon, protected areas, use of forests for recreation and other services, biological diversity and forests' contribution to national economies - is crucial to support decision-making for policies and programmes in forestry and sustainable development at all levels (FAO, 2010).

Tropical deforestation happens because it is more profitable to cut down forests than to look after them. However, the emissions from deforestation and degradation of forests make up close to 20 per cent of the global emissions of greenhouse gases. Reducing these emissions represents one of the fastest, most significant and cost-effective options for slowing down climate change in the near term. In spite of the enormous benefits obtained from forests, large areas of the richest forests in the world have been cleared for fuel wood, timber products, and agriculture (Alonso *et al.*, 2001).

According to Fermon (2002) a wide range of human activities such as farming and logging have resulted in the degradation of biota and loss of habitats. Population increase, coupled with urbanization and industrialization over the years have led to over-exploitation of forest resources resulting in high deforestation and disappearance of some plant and animal. Emissions from land-use change, primarily tropical deforestation and forest degradation contribute to an estimated 20 per cent of total anthropogenic greenhouse gas emissions (IPCC, 2007b).

Meanwhile, non-timber Forest Products (NTFPs) are important tools for addressing poverty issues for the marginalized, forest dependent communities, by contributing to livelihoods, including food security, income, health and sustainable human development (FAO 1995c; Falconer 1997; Ahenkan and Boon 2008). Globally, an estimated 350 million people mostly in developing countries depend on NTFPs as their primary source of income, food, nutrition, and medicine (Chandrasekharan 1996; Olsen 1998; UNDP 2004; FAO 2005c). These products play a vital role in sustaining the lives of local gatherers, who must increasingly adapt to diminishing resources to stay alive (Joshi & Singh, 2010).

According to Ahenkan and Boon (2010), NTFPs provide foundation for the development of the livelihoods of forest dependent communities. They foster natural resource conservation and ecosystem services (Ruiz Pérez *et al.* 2005; Kamaljit *et al.* 2007; Shahbaz *et al.* 2007; IUCN 2008). An estimated 80% of the developing world population heavily relies on NTFPs for their primary livelihoods (FAO 1997; Shackleton & Shackleton 2004; Ahenkan & Boon 2008; Mbuvi and Boon 2008). They are important in the socio-economic, ecological, and cultural development in tropical countries (Mbuvi & Boon 2008).

Non-timber forest products (NTFPs) farming is emerging globally as an important tool for establishing sustainable forest communities and supporting forest-based livelihoods. NTFPs are of great importance to millions of people whose livelihoods largely depend on them. Increasingly, forest policies of many countries are being revised to reflect the potential of NTFPs in achieving rural development and poverty alleviation (Ahenkan and Boon, 2010).

In Ghana, various forest policies have been formulated and implemented for developing a national forest estate and timber industry. However, most of the forest policies have failed to address the role of NTFPs in achieving poverty reduction in the country. Forest policies continue to remain a major hurdle to the growth and development of NTFP in Ghana (Ahenkan and Boon 2010).

2.4 The African Case

Africa is rich in forest biodiversity.It is home to some one quarter of the world's 4,700 mammal species, including 79 species of antelope. It also has more than 2,000 species of birds – one fifth of the world's total – and at least 2,000 species of fish, alongside 950 amphibian species. The African mainland harbours between 40,000 and 60,000 plant species and about 100,000 known species of insects, spiders and other arachnids. Eight of the world's 34 biodiversity hotspots are in Africa (UNEP, 2008).

Africa contains about one-fifth of all known species of plants, mammals, and birds, as well as one-sixth of amphibians and reptiles. These species compose some of the world's most diverse and biologically important ecosystems such as savannahs, tropical forests, coral reef marine and freshwater habitats, wetlands and mountain ecosystems. These globally important ecosystems provide the economic foundation that many Africa countries rely on by providing water, food, and shelter (Case, 2006).

Forests, and the biodiversity contained within them play key roles in supporting national economic activities and providing livelihood portfolios for many in Africa. They provide valuable ecosystem services such as climate regulation, hazard protection, water conservation, watershed protection, and also provisioning goods such as fuelwood, foods and nutritional supplements, and medicinal products. Forests are at the frontline in moderating climate impacts on Africa by reducing exposure to climate extremes such as heat, drought and floods, and also the sensitivity and adaptive capacity of forest dependent people. Inarguably, forests should play a major role in national development strategies and be the entry point for climate change adaptation in Africa (Nkem *et al.*, 2008).

The past decade was marked by profound policy and institutional changes relating to environmental problems at the national, regional and international levels. Consequently, the June 1992 Rio Earth Summit saw the coming into being of many international conventions on environmental protection and biodiversity conservation. Additionally, an international debate on forests was established, thus enabling the various regions of the world to become aware of the stakes and especially threats to the tropical forest ecosystems (COMIFAC, 2006).

Across Africa and especially in West Africa, natural forests have been reduced and fragmented to less than 30% of their original area. The forest patches that remain continue to be degraded or completely lost at an alarming rate. Due to the high number of species found in these forests (biodiversity), high number of species found nowhere else on earth (endemic species), and high rate of loss, West African forests have been designated as one of 34 Global Biodiversity Hotspots. West African mountain forests are especially rare and important to protect because they contain unique ecosystems with exceptional species richness and high levels of endemism (McCullough *et al*, 2007).

Climate change and increasing climate variability threaten the attainment of the Millennium Development Goals (MDG), and some of the worst effects on human health and agriculture will be in sub-Saharan Africa, particularly in vulnerable regions (Thornton *et al.*, 2008).

Economic activities and demand for affordable fuels have led to widespread deforestation and forest degradation in developing countries particularly Africa. African countries accounted for over half of global forest loss between 2000 and 2005 and the net forest loss amounted to 3.4 million hectares per year during the period 2000–2010 (FAO, 2007b; 2011).

Out of the ten countries with the highest rates of forest loss, seven were in Africa5. Rates of forest loss are highest in western and northern Africa, which also have the smallest areas of forest cover. Although rates of forest loss are lower in southern and central Africa, the higher absolute area of forest in these regions means that the total area of forest lost per year is higher (AfDB, 2013).

Available evidence suggests that Africa's recent growth has been underpinned by increased exploitation of renewable natural resources beyond their regenerative capacity and by an increasing amount of GHG emissions. The level of environmental damage and natural resource depletion is approaching alarming proportions, threatening future growth prospects and progress achieved in social indicators (World Bank, 2012).

The carbon mitigation potentials from reducing deforestation, forest management, afforestation, and agro-forestry differ greatly by activity, regions, system boundaries and the time horizon over which the options are compared. In the short term, the carbon mitigation benefits of reducing deforestation are greater than the benefits of afforestation. That is because deforestation is the single most important source, with a net loss of forest area between 2000 and 2005 of 7.3 million ha/yr. (Nabuurs et al, 2007).

Mitigation options by the forestry sector include extending carbon retention in harvested wood products, product substitution, and producing biomass for bio-energy. This carbon is removed from the atmosphere and is available to meet society's needs for timber, fibre, and energy. Biomass from forestry can contribute 12-74 EJ/yr to energy consumption, with a mitigation potential roughly equal to 0.4-4.4 GtCO2/yr depending on the assumption whether biomass replaces coal or gas in power plants (Nabuurs et al, 2007)

Globally, hundreds of millions of households depend on goods and services provided by forests. This underlines the importance of assessing forest sector activities aimed at mitigating climate change in the broader context of sustainable development and community impact. Forestry mitigation activities can be designed to be compatible with adapting to climate change, maintaining biodiversity, and promoting sustainable development. Comparing environmental and social co-benefits and costs with the carbon benefit will highlight tradeoffs and synergies, and help promote sustainable development (Nabuurs et al, 2007)

International initiatives such as Reducing Emissions from Deforestation and Degradation (REDD+) provide performance based payments and hence incentives for the conservation of natural resources. This could potentially offer new revenue streams which facilitate the transition to greener development trajectories, if natural resource management efforts are linked to improving the livelihoods of local population (AfDB, 2013).

There is the need to plan and manage protected areas to conserve biodiversity in the face of climate change, including a greater focus on carbon storage, landscape connectivity and restoration to maintain ecosystem resilience. It will also assemble tools for enabling the role of protected areas also serve as “natural solutions” helping communities to mitigate and adapt to the impacts of climate change. It will include new knowledge and case studies in the field of ecosystem-based approaches to adaptation and mitigation, to outline a broad and bold vision which emphasizes the key role of protected areas in climate change strategies at both national and local level (IUCN, 2013).

Countries in Africa are among the most vulnerable globally to the effects of climate change because of the dependence of much of the population on agriculture, particularly rain-fed agriculture, and widespread poverty that renders them unable to withstand climate stress. Additional constraints (disease burden, debt burden, political instability, and conflict) reduce the adaptive capacity and increase the vulnerability of rural populations. Recurrent drought in many countries has demonstrated the effects of climate variability on food resources. Widespread poverty in many countries places many people facing food insecurity even in good times. Additionally, climate variability and change threaten other resources including water, forests, and fisheries. Communities in coastal areas will be impacted by projected rise in sea-level of up to 1 m in this century; some countries already experience coastal erosion and flooding (Stanturf, *et al.*, 2011).

Africa is particularly vulnerable to the effects of climate change because of multiple stresses and low adaptive capacities, arising from endemic poverty, weak institutions, and complex disasters and associated conflicts. Drought will continue to be a primary concern for many African populations. The frequency of weather- and climate-related disasters has increased since the 1970s, and the Sahel and Southern Africa have become drier during the twentieth century. Water supplies and agricultural production will become even more severely diminished. By 2020, in some African countries agricultural yields could be reduced by as much as 50%. By the 2080s, the area of arid and semi-arid land in Africa will likely increase by 5-8% (ISDR, 2008).

The Fourth Assessment Report (IPCC, 2007b) indicates that Africa's climates, ecosystems and economies have already been affected by global warming and are likely to experience further change. The adverse effects of climate change will lead to secondary effects in African countries, and in particular the poorest of these countries, resulting in diminishing subsistence capacities of natural systems and/or the durability of human settlements.

West Africa's heritage of diverse tropical forest ecosystems, range from evergreen dense humid forests, coastal mangrove forests, semi-deciduous forests, Guinea, Sudanese and Sahel savannah formations to the desert zones. These ecosystems are the major sources of wood energy, environmental services, exports of prime woods and non-timber forest products; the latter contributes substantially to improvements in food security, human nutrition, health and livelihood support generally of the estimated population of nearly 253 million inhabitants of ECOWAS (Tufuor, 2012).

A recent study by Pouliot, and Treue, (2013), using data from 1014 households in Ghana and Burkina Faso, observed that non-forest environmental products play a crucial role in rural livelihoods, especially for women and the poorest. They further stated that, forest incomes are generally small but richer households and especially men from these derive comparatively higher value from forests than other groups do. Environmental income also represents a safety net for households facing crises due to illness or death of a productive household's member, but apparently not when cropping fails.

2.5 Biological diversity of the Atiwa Range Forest Reserve

Atiwa Range Forest Reserve (ARFR), one of the country's few prominent upland evergreen vegetation noted for its biodiversity, water resources and bauxite deposit is located in the Eastern Region of Ghana. The reserve is about 145 kilometres wide from Apinamang in the west, to Kibi in the east and up to 815 metres in height. The hills stand up prominently in the surrounding areas and covered preeminently with tropical forest. There are no permanent settlements in the reserve area since communities were all founded at the foothill of the range (Kesse 1985).

The ARFR lies within the semi-deciduous forest zone of the country and it is characterized by two rainfall maxima (April to July) and (August to November) that is, a bi-modal seasonal distribution. It has an average annual rainfall of about 1588 millimetres and the average monthly temperature of 27.9 ^{0}C, an annual Relative Humidity of 78% (Akabzaa *et al.* 2007).

According to McCullough *et al*. (2007), the Atiwa Range Forest Reserve is part of an ecosystem known as the Upper Guinea Forest. It is ranked among the world's 34 most important biodiversity Hotspots. The Atewa Range plant communities are classified by botanists as Upland Evergreen Forest (UEF). Atiwa is one of only two such forests in Ghana, and is known to be very rich and unique. There are 765 different species of vascular plants known from Atiwa, including 106 Upper Guinea endemic species. Many of Atiwa's plants are used by surrounding communities in medicine, as food, or as building materials.

The reserve boasts of countless endangered and rare species of plants, animals, and other microbes. Among this profusion are insects and arachnid's diversity, fish species, amphibians, reptiles, birds, and mammals. Insects and other invertebrates are the most important animals in the Atewa forests. They provide a number of invaluable ecological services, such as pollination of plants, soil production and fertilization, removal of organic waste, and providing food for most vertebrates, such as frogs, lizards, birds, and many mammals. The forests of Atewa harbor probably tens of thousands of species of insects and other invertebrates, some still unknown to science. Recent scientific expeditions to Atewa discovered several new species of butterflies, katydids, dragonflies, and other small animals.

The streams of Atewa are still relatively clean and undisturbed, and show relatively low fish species diversity, which is typical of undisturbed forests. Sixteen species of fish have been recorded from Atewa, some of which have a great potential in the aquarium trade, and could be sustainably harvested (ibid. p. 25).

The amphibian fauna of Atewa, which includes frogs, toads, and legless, snake-like caecilians, is rich and unique. Over 30 species are known from Atewa, and all are typical of healthy, undisturbed forests. Almost a third of all amphibian species in Atewa are considered threatened, and their populations in this forest are some of the last ones remaining in the world. Amphibians play an important role in the forest habitats of Atewa, both as predators of insects and other small organisms, and as food for reptiles, birds, and mammals (ibid. p. 25).

Reptiles include lizards, snakes, turtles, tortoises, and caiman. While the reptiles of Atewa have never been systematically surveyed, it is clear that its forests harbor an interesting and diverse fauna of these animals. While a few species of snakes occurring in Atewa are venomous and should be treated with respect, most reptiles living there are completely harmless. All reptile species are highly beneficial for the forest ecosystem and the surrounding areas by controlling rodent and insect populations. Many reptiles are becoming rare because of the loss of their habitats, and are now considered threatened (ibid. p. 25).

The Atewa Range Forest Reserve is one of the most important bird sites in Africa. It is classified as an Important Bird Area, with over 150 species recorded within its borders. Six of these species are of conservation concern, being ranked as either Vulnerable or Near Threatened, and one species (*Nimba Flycatcher*) occurs nowhere else in Ghana. Birds are vital members of this forest community. They are primary seed dispersers, and many tree species would not be able to reproduce without birds' help. Many birds are insectivores, keeping in check populations of plant-eating insects, and stopping their populations from excessive growth (McCullough *et al*, 2007).

The forests of Atewa are home to a wide range of rare and threatened forest mammal species. Over 40 species have been recorded from Atewa, including 6 species of primates (monkeys and bush babies), pangolins, civets, and duikers. Unfortunately, these species have suffered greatly from negative changes to their habitat caused by both selective logging and construction of roads and, more importantly, widespread, illegal bushmeat hunting. Unfortunately, unregulated, illegal logging poses a serious threat to survival of many parts of the Atewa forest (McCullough *et al*, 2007).

The total population of the district is approximately 110,622. The distribution of the population by sex shows more females (50.6%) than males (49.4%) are residing in the district. Comparing population by the locality type, there are more people in the rural areas than the urban centres. The urban population constitutes 33.3 percent whiles the rural population has 66.7 percent. The total sex ratio is 97.7 percent implying that for every 100 counts of females in the district, there are almost 98 males. However, the sex ratio in the rural area is almost the same with 99.6 percent which shows that for every 10 females there are almost 10 males. Children under 15yeas in the district have the highest population of 44,111 which represents 39.9 percent of the population followed by 30-59 years (27.1%). The age group 15-24 years (youth) recorded 17.3 percent while Age 25-29 recorded the lowest with 6.8 percent of the total population (GSS, 2012).

The economy of the Atiwa District is predominated by agriculture which employs about 60% of the labour force. The agriculture value chain all together employs a larger number of people. This is because most of the small and medium scale enterprises are of food processing, especially gari making and oil palm extraction. Other industrial activities in the district are mining principally located in Abomosu and Kwabeng. Trading and services sector is also well functioning. The service sector employs about 34.4% and the mining sector employs 6.6% of the total labour force in the district (Atiwa District Assembly, 2014).

2.6 Sustainable livelihood

There is a lack of consensus about the meaning and criteria used to describe the concept of poverty. Whereas poverty has generally been defined using income or consumption criteria by most international bodies, anytime poor people are asked to define poverty the concept of income is just one of the issues they outline (Chambers, 1987). Other issues raised include: a sense of insecurity or vulnerability; lack of a sense of voice vis-à-vis other members of their household, community or government; and levels of health, literacy, education, and access to assets, many of which are influenced by the scope and quality of service delivery (Farrington *et al.*, 1999).

What is poverty – and how it can best be addressed – are central questions at conceptual and practical levels in international development. Increased donor commitment to tackling poverty has made the search for answers more urgent. Thus any attempt to tackle poverty and to deal with it successfully should be broad base and all encapsulating. It should also be lasting and sustainable (Farrington, *et al.*, 1999). It is important to emphasize that a detailed understanding of people's livelihoods can only be established through participatory analysis (Turton, 2000). SL analyses fully involve the local people to let their knowledge, perceptions, and interests be heard (Krantz, 2001).

The idea of sustainability emerged at the centre stage of international deliberation when the Brundtland Report was launched in the late 1980's and the early 1992 when the United Nations Conference on Environment and Development expanded the concept, advocating for the achievement of sustainable livelihoods as a broad goal for poverty eradication (Krantz, 2001).

Subsequently, a sustainable livelihoods (SL) framework was devised by the major state bodies and international organizations (Farrington *et al.*, 1999, UK-DFID, 1997) framework is an analytical device for improved understanding of livelihoods and poverty. The SL approach based on this framework supports poverty eradication by making enhancement of poor people's livelihoods a central goal of development efforts (Farrington, *et al.*, 1999).

According to Scoons (1998) a livelihood '... comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks, and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base' (Farrington, *et al.*,1999).

The concept of Sustainable Livelihood (SL) is an attempt to go beyond the conventional definitions and approaches to poverty eradication. These had been found to be too narrow because they focused only on certain aspects or manifestations of poverty, such as low income, or did not consider other vital aspects of poverty such as vulnerability and social exclusion. It is now recognized that more attention must be paid to the various factors and processes which either constrain or enhance poor people's ability to make a living in an economically, ecologically, and socially sustainable manner. The SL concept offers a more coherent and integrated approach to poverty (Krantz, 2001).

CHAPTER THREE

METHODOLOGY

3.0 Research Design

The study employed the mixed method of social science research, that is, it combined both the quantitative and qualitative research methods in undertaking the study (Johnson *et al.*, 2007). The mixed method helps broaden understanding and makes social problem more intelligible than using in strict terms, either quantitative or qualitative approach. With the development and perceived legitimacy of both qualitative and quantitative research in the social and human sciences, mixed method research, employing the combination of qualitative and quantitative approaches, has gained popularity (Creswell, 2009). Moreover, the problems addressed by social sciences are complex, and the use of either approach is inadequate to address this complexity (Creswell, 2009) hence the adoption of this approach.

As far as quantitative approach is concerned, the study used survey and collected the data by sampling from three communities along the Atiwa Range Forest Reserve (Akyem Akropong, Banso and Larbikrom). The combination of sampling and inferential statistics in survey research means that it has enduring strengths as an effective way of identifying and examining general patterns in association with all, most or even large percentage of the population (Curtis & Curtis, 2011). This paradigm assumes the sample is representative of the population. The choice of quantitative approach was to provide a more reliable and objective findings. It also allows the use statistics to make generalized finding and reduce subjectivity of the researcher in the methodology.

However, there is a fundamental problem associated with quantitative research approach as it suffers inherent biases. Quantitative surveys often suffer from acquiescence bias, where respondents tend to agree with whatever options or statements are presented to them (Ray, 1990). Thus, respondents may not give their own understanding and views on an issue and may also not show in-depth understanding of the issue in question. A study conducted by Lorraine Whitmarsh (2009) concluded that, compared to checklist surveys, research that examines unprompted and contextual beliefs provides a more revealing insight into, and a more accurate reflection of, public understanding of phenomenon especially climate change. According to him the qualitative approach is most appropriate to get the respondents' own views and understanding on the issue without being prompted.

In order to deal with the inherent problems with quantitative approach and to have balanced findings, the study also employed the case study design, a qualitative approach. A case allows the researcher to have an in-depth understanding of the phenomenon under discussion. Respondents' own understanding of the phenomenon is further ascertained. More importantly, the passion which is shown by respondents in answering questions gives an indication of how important an issue is to a group of people. As it became increasingly obvious to some researchers that subjective human feelings and emotions were difficult (or impossible) to quantify, qualitative (anti-positivist) analytical methods were evolved, which took more account of the 'soft', personal data (Williaman, 2011).

3.1 Population of the study

The population of the study included community leaders (assembly members, traditional authorities, the aged and other opinion leaders), farmers, hunters, and chain saw operators were involved in the focus group discussions (FGDs). This was to help get historical views, experiences and in-depth perspective of how these communities understood and perceived the issue of climate change and how it has so far affected the utility they derived from the forest.

As far as the survey technique was concerned, all members of the selected communities were a target for data gathering and analysis. The unit of analysis therefore was every member of the selected communities (Akyem Akropong, Banso and Larbikrom) who benefits directly or indirectly from the reserve. Because the benefits the reserve provides affect every member of these communities, the research drew on all the experiences of every member of these communities particularly from 18 years and above in order to make conclusions and outcomes all embracing.

3.2 The Study area

3.2.1 Location

The Atiwa Range cuts across several political administrative districts in the Eastern Region of Ghana. However, the three communities selected for the study form part of the larger Atiwa District Assembly with its administrative capital at Kwabeng which is situated at the foot of the Atiwa Range. The Atiwa District lies between longitudes 0° 3‘ West and 0° 50

East and latitudes 6° 10ʹ North and 6° 30ʹ North. The District is bounded on the North by Kwahu West and Kwahu South Districts, on the North-East by the Fanteakwa District, East Akim to the South-East, Kwaebibrim to the South and Birim North to the West. The Atiwa District covers an estimated area of 2,950 square kilometres (Figure 1)

3.2.2 Site characteristic

The Atiwa District is located within the moist semi-deciduous forest. The forest reserve covers the Atiwa Scarp and its surroundings. It lies in the wet semi equatorial zone characterized by a bi-modal rainy season, which reaches its maximum during the two peak periods of April-July and September-October every year. The annual rainfall is between 1,250mm and 1,750mm with temperatures ranging between a minimum of 26°C and maximum of 30°C. A relative humidity of 65-75 percent during the dry season and 75-80 percent in the rainy season is a characteristic of the district. Commercial tree species covering the 12 percent land area include; Wawa *(Tripochiton scleroxylon*), Odum (*milicia exelcsa*), sapele (*Guthaphragong*) and mahogany (*Kaya ivoreensis*) etc.

The predominant soil type in the Atiwa District is usually reddish-brown and well-drained loam, located on the relatively high lands. Food crops like cassava, maize, plantain, cocoyam and yam as well as tree crops like cocoa, oil palm, coffee and citrus thrive well on it. The District is endowed with mineral deposits (gold, diamond, bauxite and kaolin), which are found in the Birim river basin around Enyiresi, Abomosu, and Kwabeng. Bauxite and manganese are also found at Asamama and surrounding area whilst kaolin deposits are found at the Atiwa Ranges (Atiwa District Assembly, 2014).

The District is rich in timber and water resources. The ARFR covers about 100 square kilometres of the district and contains various timber species and medicinal plants, and it is good attractions for eco-tourism. Adenchemsu, Sea Abena, Akuku, Kankan, Abresu, Awusu, Kokobeng, Frempong, Kade, Subri, Anikorkor are some rivers and stream in the district. The Birim, Densu and Pra rivers trace their sources from the Atiwa ranges which are potential source of water for irrigation and fishing (Atiwa District Assembly, 2014).

3.2.3 Socio-cultural, demographic and economic characteristics

The demography of the communities within the District is dynamic with the indigenous ethnic group being the Akyem who speak the Akan Language. The area also accommodates other ethnic groups like Ewes, Ga-Adangbes, Akwapims, who are mainly migrant cocoa farmers who moved to the area in the twentieth century. The other ethnic groups in the District are Frafras, Dagartis, Guans, Brongs, Hausas and Fulanis. Traditionally, Osagyefo Amoatia Ofori Pannin II is the Paramount Chief of Abuakwa Traditional Area with his seat at Kyebi, capital of East Akim Municipal Assembly (ibid. p. 6).

3.3 Types and sources of data

The study relied on both primary and secondary sources of data. Primary data was obtained from the leaders of the communities including assembly members, traditional authorities, opinion leaders, farmers, hunters, and chain saw operators through focus group discussions, in-depth interviews and survey.

The main secondary data that were relevant to the study include climatic data obtained from the Ghana Meteorological Department (GMet) from 1961-2010. Specifically: rainfall and temperature data for the study from the periods 1961-2010 and 1972-2012 respectively were used for the analysis. Remote Sensing (RS) data from 1991 to 2013 demonstrating the trends in nature of the study area was obtained from the Remote Sensing and GIS Laboratory of the Department of Geography and Resource Development, University of Ghana. Finally, base map from the Survey Department as well as other relevant data from the district assembly informed the analysis and study conclusions.

3.4 Sample size

A sample size of 200 was originally planned for but at the end of the survey 184 respondents were selected comprising of 73 from Akyem Akropong, 72 from Banso and 40 from Larbikrom. Forty-four individuals were purposively selected for the in-depth interviews and FGDs. This number consisted of 42 people for the focus group discussions, and two officials; the Atiwa District Planning Officer and the Range Commander in charge of the Anyinam portion of the reserve.

According to Long (1997), the minimum number require for a binary logistic test should be hundred and that if the sample size of a binary logistic regression in a study is less than 100, the researcher should increase 100. Thus, as the study used binary logistic it is justifiable to use a sample size of 184.

3.5 Sampling technique

The simple random sampling technique was employed to select questionnaire respondents. With this technique, any member of the community above age 18 years had equal chance of being selected to participate in the study. This was against the backdrop that all community members above age 18 have knowledge of the Atiwa Forest Range. On the other hand, the purposive sampling technique was employed to select respondents to interview. This technique enabled opinion leaders and individuals who had in-depth knowledge in the area and the subject under investigation. This enabled enabled respondents to bring into the discussion past personal experiences of communities along the reserve vis-á-vis the current climate milieu. Communities sampled were Akyem Akropong, Banso and Larbikrom.

3.6 Data collection

Structured questionnaires were used to gain relevant information from respondents and an interview guide designed to solicit relevant information. The questionnaires contained close ended questions and were distributed to simple randomly selected respondents from the three study communities. The researcher also carried out in-depth interviews with key informants and opinion leaders as well as focus group discussions with selected respondents with the quest to get detailed information on the phenomenon.

3.7 Data analysis

Data from the questionnaire was first coded; the Statistical Package for Social Sciences (SPSS) and Microsoft Excel were used to analyse the data generated from the field. Three key statistical techniques were used to assess the relationship between dependent and independent variables.

Firstly, the Pearson Chi-square test was used to measure the significance and relationship between gender of respondents' and their perception of climate change; location of respondents and accessibility to the conserved forest; location of respondents and the state of their activities twenty (20) years ago compared to current trend.

Secondly, the McNemar-Bowker Chi-square test was employed to ascertain respondents' change in opinion regarding current state of livelihood activities and that of twenty (20) years ago. This test is useful since it offers the opportunity to statistically test respondents' current livelihood outcomes relative the past.

The binary logit model was employed in assessing the factors influencing the adoption of climate change adaptation strategies. It has the advantage to predict the probability of individual been ready to meet future challenge that may cause the decline of the forest resulting from climate change or not, which was used as a proxy for vulnerability or not (Gujarati, 2004). The model is specified as:

$$Logit(Y_i) = In\left(\frac{P_i}{1-P_i}\right) = \beta_o + \sum \beta_i X_i + \mu_i \quad (1)$$

where Yi = dummy for vulnerability which is equal to zero (0) if an individual is vulnerable to climate change and variability and one (1) if an individual is not , X_i= independent variables influencing vulnerability , β_i = regression coefficients to be estimated, β_o= intercept regression coefficient,

P_i = the probability to vulnerable and μ_i =error term

Equation (1) can be further written as:

$Logit(Y_i) = In(\frac{P_i}{1-P_i}) = \beta_o + \beta_1 Awa + \beta_2 + \beta_3 E_{du} + \beta_4 Temp_p + \beta_5 Ag_e + \beta_6 Alt_l + \beta_7 Gen$

$+ \beta_1 Acc + \beta_3 Rain_p + \beta_3 Asset_t + \mu$.. (2) (Appendix 3)

Another binary logit model was used to determine the effect of climate change on ecosystem and livelihood outcomes. It has the advantage to predict the probability of individual perceiving that climate change has an effect on the ecosystem and livelihood outcomes or not (Gujarati, 2004). The model is specified as:

$Logit(Y_i) = In(\frac{P_i}{1-P_i}) = \beta_o + \sum \beta_i X_i + \mu_i$.. (1)

where Yi = dummy for the effect of climate change on ecosystem and livelihood outcomes (1) if the individual perceives an effect of climate change on ecosystem and livelihood outcome and zero (0) if an individual perceives otherwise , Xi = independent variables measuring individuals' perception, β_i= regression coefficients to be estimated, β_o = intercept regression coefficient, P_i = the probability of individual perceiving that there is an effect of climate change and variability on ecosystem and livelihood outcome. μ_i =error term

Equation (1) can be further written as:

$Logit(Y_i) = In(\frac{P_i}{1-P_i}) = \beta_o + \beta_1 Age + \beta_2 Gen + \beta_3 E_{du} + \beta_4 Occ + \beta_5 Com + \beta_6 Stm + \beta_7 Drt$

$+ \mu$.. (2)

(Appendix 4)

The data from the in-depth interview was be transcribed, sorted out and analyzed thematically in a way that best answers the research questions of the study.

CHAPTER FOUR

RESULTS

4.1. Demographic data

4.1.1 Towns and Sex of respondents

A total of 184 respondents were sampled in three communities (Akyem Akropong, Banso and Larbikrom) in the Atiwa District of the Eastern Region for the survey. Out of this 21% were from Larbikrom, 39% from Banso and 40% were from Akyem Akropong. 53.8% out of the total number sampled were males and 46.2% were females (Table 1).

Table 1: Demographic Characteristic of Respondents (field data)

Demographic Characteristics of Respondents		Frequency	Percentage
Town of Origin	Larbikrom	39	21.2
	Banso	72	39.1
	Akyem Akropong	73	39.7
	Total	***184***	***100***
Gender	Male	99	53.8
	Female	85	46.2
	Total	**184**	**100**
Age	18-24	7	3.8
	25-30	26	14.1
	31-35	18	9.8
	36-40	25	13.6
	41-45	34	18.5
	46 and above	74	40.2
	Total	**184**	***100***
Occupation	Farming	144	78.3
	Trading	20	10.9
	Herbal Specialist	6	3.3
	Other	14	7.5
	Total	***184***	***100***
Education Background	Basic	69	37.5
	Elementary	48	26.1
	Secondary	17	9.2
	Middle School	44	23.9
	Other	6	3.3
	Total	***184***	***100***

Majority of respondents 40% were 46 years and above. 18% were between 41 and 45 years; 14% were between the ages 25 and 30 years whereas 13.6% were between the ages 36 and 40 years. 10% of the respondents were within the age bracket of 31 and 35 years and 7 representing 3.8% of the respondents were between 18 and 24 years.

The occupational characteristics of respondents were: 78.3% farmers, 10.9%- engaged in trading activities, herbalists (3.3%) and 7.5% engaged in other activities, such as hunting, carpentry, and a combination of these activities (Table 1).

4.1.2 Level of Education of respondents

Respondents' educational levels were also measured based on the educational system currently running and those that were run in the past. Out of the total number of 184 people sampled, 38% said they received basic level education, 26% had elimentary education and middle school education (24%). Respondents who had secondary education consituted 9%, and 3% with other forms such as vocation, technical while some never received formal education at all (Table 1). See Appendix 5 for a sample of the questionnaire.

4.2 Climate Change

4.2.1 Temperature and rainfall of the area

Temperature records obtained from the Ghana Meteorological Agency of the area (using proxy data from Akim Oda) from 1972 to 2011 show an increasing trend since 1972 (Figure 1).

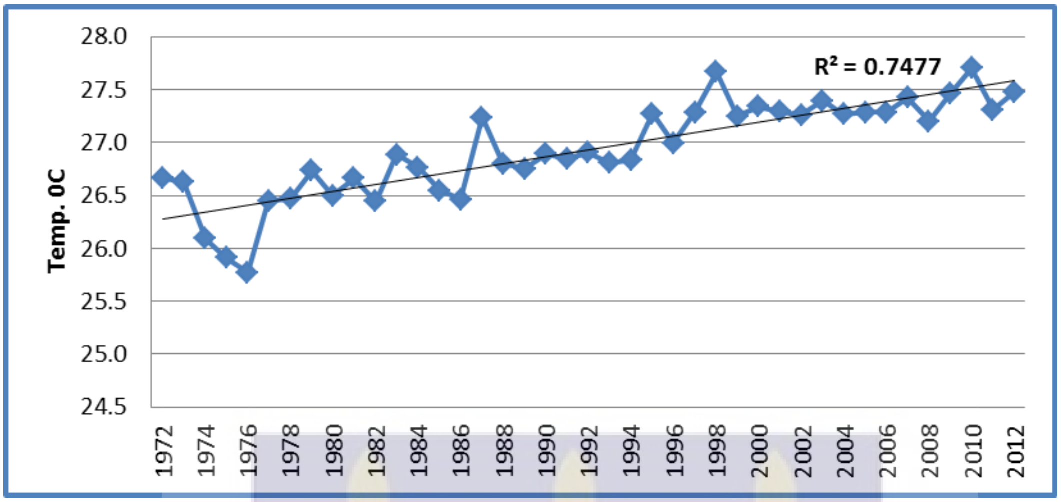


Figure 1: Temperature of the area between 1972 and 2011
Source: GMet, 2014)

Trend analysis for rainfall was also done for area from 1961-2012. Rainfall has seen a slightly decreasing trend since the 1960's (Figure 2).

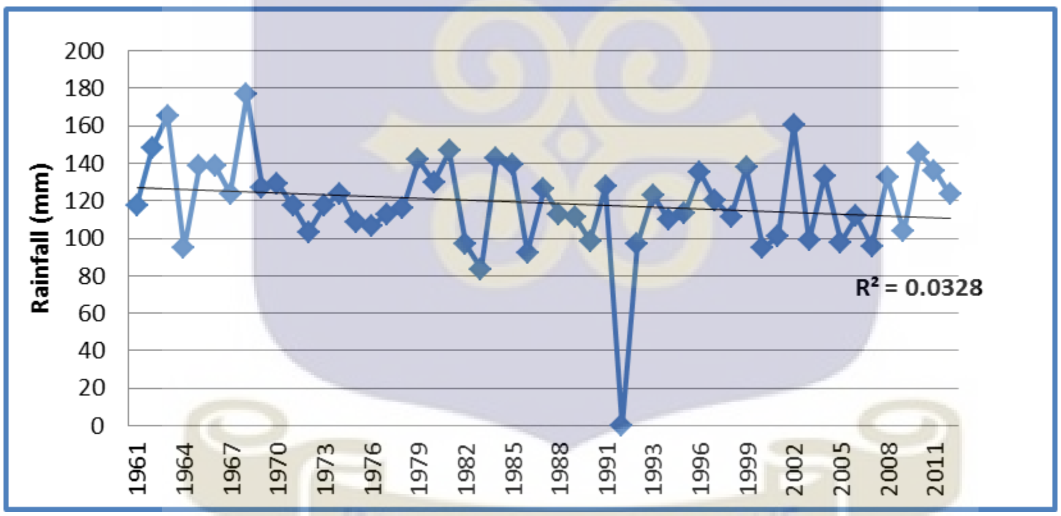


Figure 2: Mean annual rainfall of the study area (1961-2012)
Source: GMet, 2014)

4.2.2 Knowledge about climate change

Overwhelming majority of the locals 180 out the total of 184 respondents (98%), said they had heard about climate change and therefore know about it, whilst 1% said they had not heard about it and another 1% said they were not sure whether they had heard it. Most respondents (86%) said they first heard the phenomenon on radio and 11% said they heard it on television. The remaining 3% said they heard it on other platforms such as agriculture extension officers, newspapers and so on. It also became evident from the FGDs that majority of participants have heard about it and almost all of them said they heard it on radio.

4.2.3 Respondents' Understanding of Climate Change

A list of items connected to the concept was provided for respondents to choose multiple options which best describe climate change as they have observed. 24% of respondents said that rainfall variability is the first thing they think of any time they hear about climate change, 20% were of the view that intense sunshine, high temperature and variable rainfall are what they think of whenever they hear about climate change and changes in weather pattern. 14% of the respondents also perceived climate change as high temperatures and rainfall variability, whereas 12% viewed climate change as changes in sun's activity especially its intensity. 10% of respondents thought that intense sunshine and rainfall variability were the indication of climate change. Others also gave varied interpretation of their perception of climate change, such as prolonged dry season, flooding, wind storms and so on. The reasons given moreover, did not differ ($X^2 = 9.67$, df = 11, p >0.05) gender nor location of respondents.

4.2.4 Causes of climate change

Most (86%) respondents said they had an idea of what could cause climate change, 6% did not know what the causes of climate change were and 8% said they were not sure what the causes climate change is.

Majority (46.2%) respondents were of the strong believed that cutting off trees in the environment would cause climate change. 18.5% agreed that cutting trees without replacing them together with mining activities are likely to cause disruption of climatic pattern and 14.7% said tree cutting, mining and use of agro-chemicals are the main causes of climate change (Figure 3).

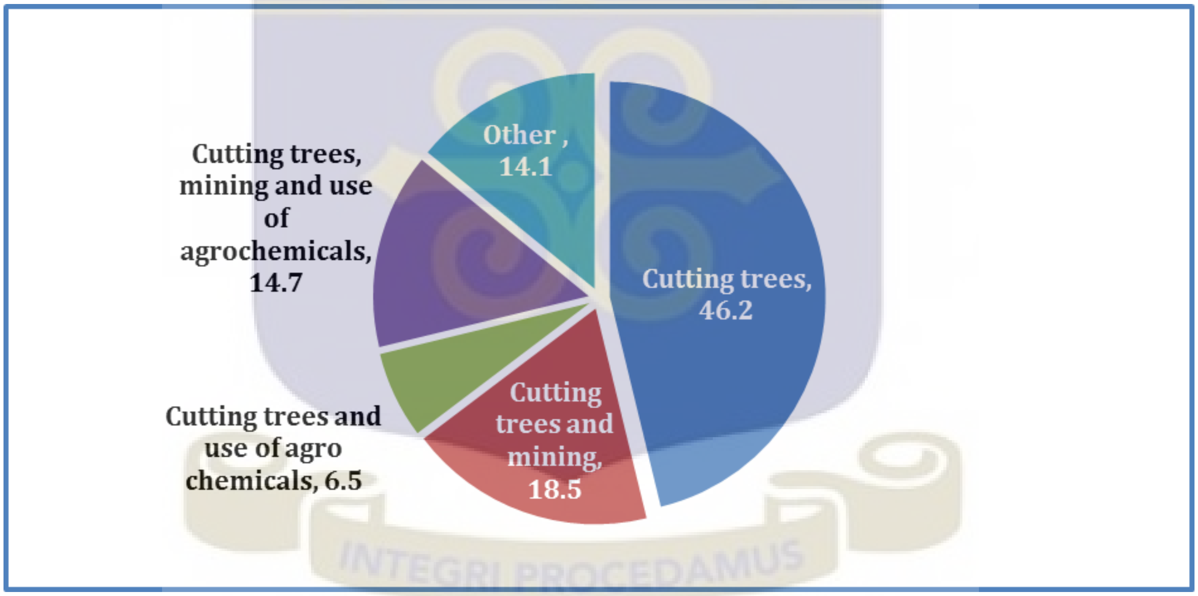


Figure 3: Human induced factors that cause climate change as identified by respondents (%)

4.2.5 Respondents' perception of rainfall and temperature

With regards to pattern of rainfall since 1990, (83.7%) respondents said pattern in the area was regular with 12.5% indicating it was irregular while 3.8% said they were not sure.

Majority of respondents (79.9%) perceived rainfall levels (quantity) in the past were very high whereas (5.4%) believed the area experienced variable rainfall in the past.

In contrast to the past, majority of respondents (67.9%) perceived current rainfall to be variable, while 14.7% thought that rainfall levels now were normal and (8.7%) believed there is low that rainfall now.

The perception of respondents with regards to rainfall in the past did not differ. Most people from Larbikrom (93%) indicating that rainfall levels were very high in the past followed by Banso (95.5%) and Akyem Akropong (80.2%) perceived high rainfall levels in the past. With regard to sex, majority of respondents (86%) being males perceived past rainfall to be very high and 82.6% of females thought rainfall levels in the past were very high (Table 3).

Table 2: Comparing how Location and Sex perceived rainfall levels in the past

		Description of past rainfall levels of this area				**Total**
		Normal (%)	Variable (%)	Very high (%)	Low (%)	**(%)**
Location	Larbikrom	5.6	7.4	85.5	1.2	100.0
	Banso	1.4	5.5	93.1	0.0	100.0
	Akyem Akropong	9.0	9.8	80.2	1.0	100.0
Sex	Male	6.1	8.1	83.8	2.0	100.0
	Female	5.7	10.6	82.6	1.1	100.0

From (Table 3), majority respondents (70.8%) from Banso perceived rainfall levels now are variable followed by (68.5%) respondents from Akyem Akropong and (61.5%) from

Larbikrom indicated that recent rainfall levels are variable. With regards to sex, majority (70.7%) of males said current rainfall is variable whereas (64.7%) females said current rainfall has been a variable one.

Table 3: Comparison between location and sex described recent rainfall levels in the area

		Description of recent rainfall in this area					**Total**
		Normal (%)	Variable (%)	Very high (%)	Low (%)	Very low (%)	
Location	Larbikrom	20.5	61.5	17.9	0.0	0.0	100.0
	Banso	9.7	70.8	0.0	18.1	1.4	100.0
	Akyem Akropong	16.4	68.5	11.0	4.1	0.0	100.0
Sex	Male	17.2	70.7	5.1	6.1	1.0	100.0
	Female	11.8	64.7	11.8	11.8	0.0	100.0

4.2.8 Locals Perception of Temperature

When respondents were asked to indicate how they perceived temperature of the area is in recent times, majority (98.4%) said they feel an increasing temperature whilst 1.6% said temperatures are reducing (Appendix 3).

4.2.9 Importance of vegetation in moderating local climate

The majority (97.8%) said that indeed vegetation affected climate of the area. the major reason given was that vegetation provided shade, aids in water cycle and stabilizes of local temperature (33.9%) and 23.8% believed that vegetation was important in the hydrological cycle and stabilizes temperature. Some (13.8%) also said that plants provided shade and enhanced the process of water cycle, whereas (11.6%) of respondents thought it served as wind breaks and stabilized temperature.

4.3 Ecosystem Services provided by the Atiwa Range

4.3.1. Remote Sensing Data of the ARFR and its environs (1991, 2002 and 2013)

In 1991, (Table 4) built up area formed 4.58% (43340400.00ha) of the forest its periphery and by 2002 settlement and roads of the reserve had dropped slightly to 4.24% (40082400.00ha), however between 2002 and 2013 human settlement and roads in the area had more than doubled to 8.95% (84658500.00ha).

Vegetation (secondary forest) of the entire Atiwa area increased progressively from 1991 to 2013. The total vegetation cover constituted 60% (569346000.00) of the area in1991 and this increased to 64.48% (40082400.00) in 2002. By 2013 it had increased to 66.06% (624895000.00ha) of the area (Table 9).

With regards to forest (primary forest), in 1991 it constituted 35.23% (333260000.00) of the entire Atiwa area. This decreased to 31.28% (295897000.00) by 2002 and further plummeted to 24.99% (236393000.00) by 2013, (Figures 5a, b and c).

Table 4: Land use change in and around the ARFR, from 1992-2013

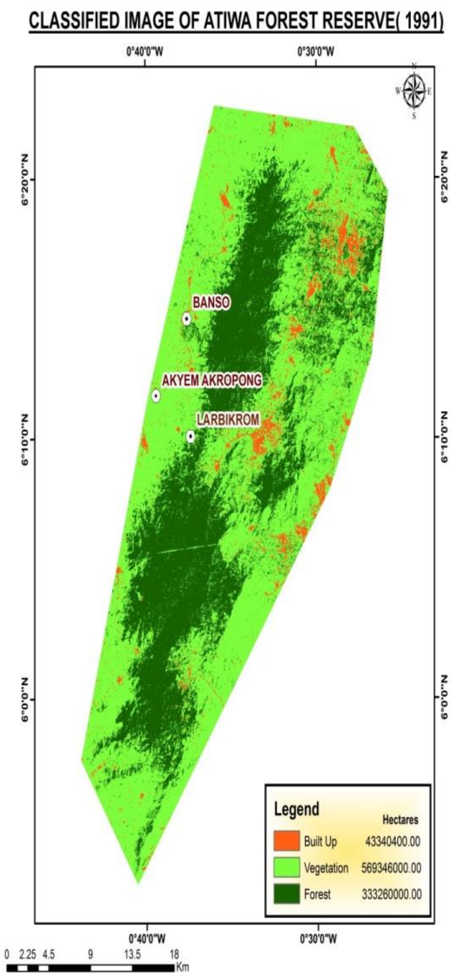
Land use Activity	1991		2002		2013	
	Ha	%	Ha	%	Ha	%
Built up	43340400.00	4.58	40082400.00	4.24	84658500.00	8.95
Vegetation	569346000.00	60.19	609968000.00	64.48	624895000.00	66.06
Forest	333260000.00	35.23	295897000.00	31.28	236393000.00	24.99
TOTAL	945946400.00	100.00	945947400.00	100.00	945946500.00	100.00

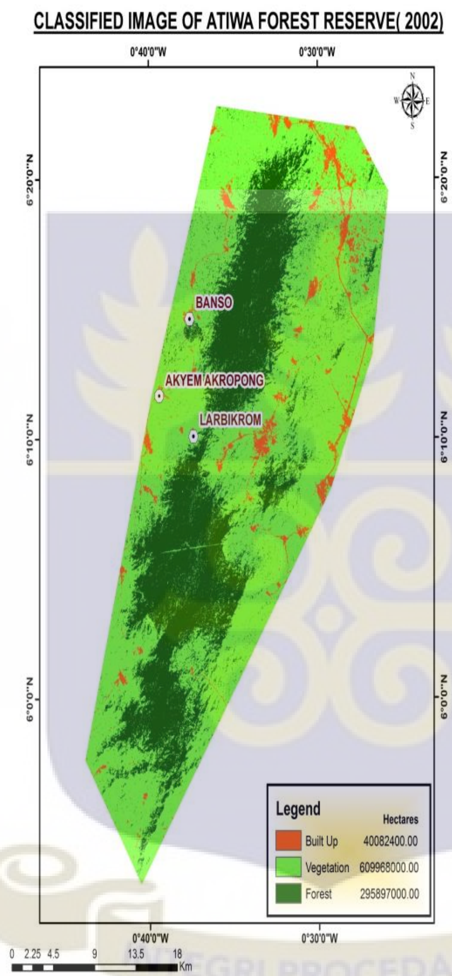
A change detection analysis was used in the area (Appendix1) between 1991 and 2013. The tables showed changes detected in bareground, vegetation (secondary forest) and forest (primary forest) over the past twenty-five years in the area. The results (Appendix 3a) shows that bareground that remained the same between 1991 and 2002 was 1909.89ha representing 44.07%. Within the same period bareground that changed to vegetation was 2380.95ha which is 54.94%. However, the bare ground that changed to forest was only 43.2 ha or 0.99%. The secondary forest that changed to bare ground with in the same period was 2036.07 ha which is 3.58% and secondary forest that remained the same was 50105.61 ha or 88.01% while vegetation that changed to forest between 1991 and 2002 was 4792.95ha or 8.42%. Finally, forest that changed to bare ground was 62.28ha or 0.19% while forest that changed to vegetation was 8510.22ha or 25.54% and 24753.51ha or 74.28% of forest remained the same.

From the change detection (Appendix 2) bare ground that remained the same for the period was 3206.07ha representing 79.99%, and the bare ground that changed to vegetation was 798.84ha which is 19.93%. Bareground that changed to forest was only 3.33ha which is 0.08% and with an image difference of 4457.61 ha (111.21%) shows and increase in bare ground within the period.

Vegetation that changed to bareground was 4709.97ha or 7.72% and the vegetation that remained the same was 53993.79ha which is 88.52% and the vegetation that changed to forest was just 2293.02ha which is equivalent to 3.76%. With an image difference of 1492.74 ha (2.45%) which means that the area witnessed increase in vegetation.

Finally, the last decade (2002-2013) marked a phenomenal decrease in forest of the area as shown by the negative image difference, -5950.35ha or -20.11%. Forest that changed to bare ground was 549.81 or 1.86%, and forest that changed to vegetation was 7696.89ha or 26.12%. 21342. 96ha or 72.13% forest remained the same.





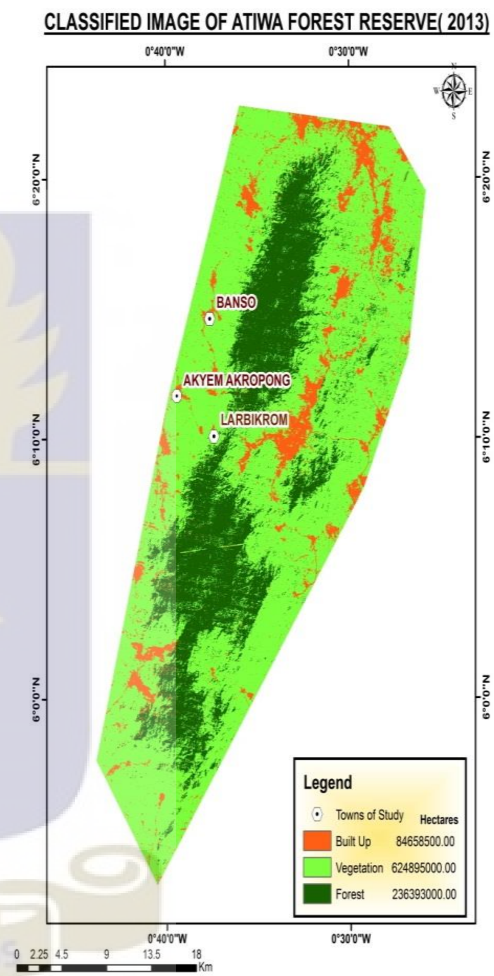


Figure 4a: Land cover changes of ARFR 19991

Figure 4b: Land cover changes of ARFR 2002

Figure 4c: Land cover changes of ARFR 2013

Majority of respondents (69.0%) said that the forest is not accessible, and (21.2%) said that the forest is accessible. During the FGDs, though majority said the reserve was not accessible, they pointed out however that, sometimes some people in their communities go in for other non-timber product like herbs for medicine. This divided opinion was obvious (χ^2 = 33.46, df =4, p<0.05) between respondents from the different communities and accessibility of the (Table5).

Table 5: Association between towns of respondents and whether they see the forest as a protected area

Variables		**Forest accessible to community members**			**Total**
		Yes (%)	No (%)	No sure (%)	
Home town	Larbikrom	12.8	74.4	12.8	100.0
	Banso	6.9	88.9	4.2	100.0
	Akyem Akropong	39.7	46.6	13.7	100.0
	Total	21.2	69.0	9.8	100.0

Majority (79.5%) of respondents said that the forest is a protected area, 13.4% said that the forest is a sacred grove where chiefs are buried so it is forbidden to enter it. 7.1% gave varied opinions on the matter, and are represented as other (Figure 5).

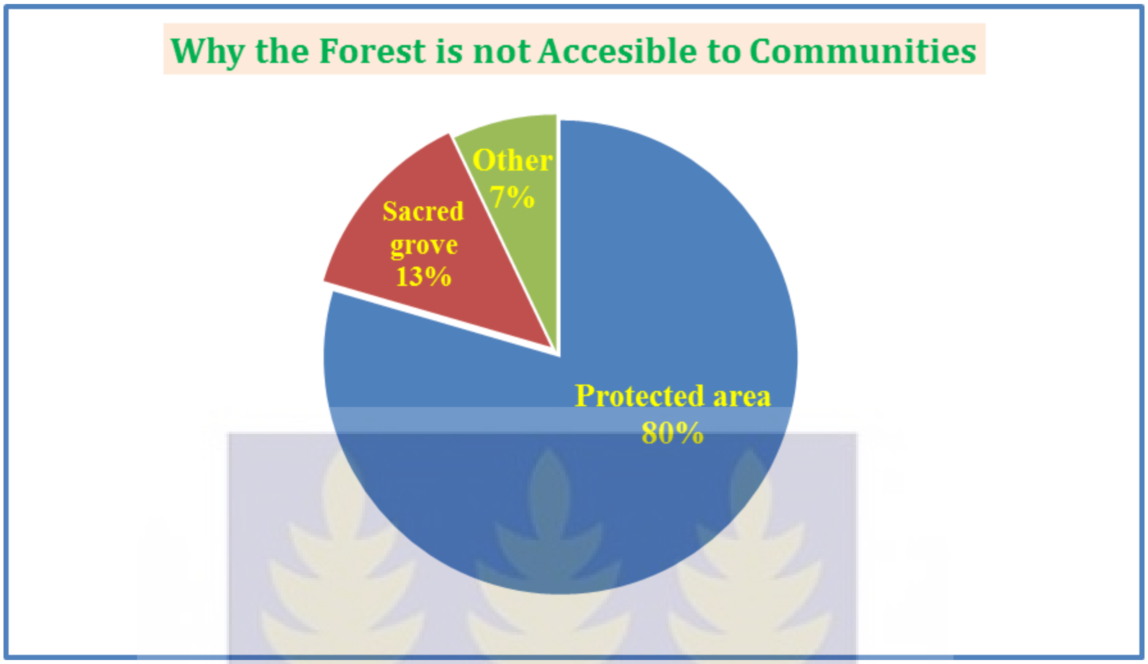


Figure 5: Reasons the forest is not accessible to fringe communities

4.3.3 Tangible benefits

Identifying tangible benefits excluding timber products they got from the forest, majority of the people (49.5%), indicated that they got snail, mushrooms, honey, medicine, and water, sponge, mortar, and pestle while (21.2%) said they obtained snail, mushrooms, honey, medicine, and water from the forest a further 19% said the major tangible goods they obtained the forest are snail, mushroom, pharmaceuticals and meat.

4.3.4 Intangibles from the forest

Out of the total number interviewed (30.4%) agreed that as a result of the forest, rainfall has been good in the area, temperatures are moderated, and towns are protected from wind storms, moreover (23.4%) respondents were of the view that the forest aided in rainfall and also helped regulate temperature so they do not experience temperature extremes. It is important to note that 8.2% identify the invaluable contribution of the forest to the hydrological (water) cycle. The importance of forest in reducing the threat of wind storm was also acknowledged by respondents. During the FGDs, participants mentioned the above benefits as the intangibles they got from the forest.

4.3.5 State of benefits in the past and present

Almost all respondents (92.9%) thought benefits they were in abundant twenty or so years ago, and 2.7% said these benefits were high, and another 2.7% were not sure.

Assessing the state of these benefits now, (44.6%) rated the current state of ecosystem services as low, 35% said the current state of benefits from the forest was moderate, whereas 10.9% said the state of these benefits now was very low. 1.6% and 2.2% however, were of the view that these benefits are abundant and high respectively, and 5.4% were not sure of the state of ecosystem services the forest now provides. Opinions from gender perspective about the state of ecosystem services were not different by respondents across the three communities (χ^2=10.905, df=6, p>0.05). Almost all female and male respondents believed that ecosystem services in the past were abundant (Table 6).

Table 6: How men and women rated the state of ecosystem services in the past

Gender	The state of ecosystem services in the past (%)				Total
	Abundant	High	Low	Not sure	
Male	90.9	2.0	2.0	5.1	**100.0**
Female	95.3	3.5	1.2	.0	**100.0**
Total	**92.9**	**2.7**	**1.6**	**2.7**	**100.0**

There was no significant difference in the perception of changes in the in the current state of benefits (χ^2=13.475, df=10, p>0.05) (Table 7).

Table 7: Association among towns of respondents and current state of the benefits with chi-square test

Town	State of these benefits in recent times (%)						Total
	Abundant	High	Moderate	Low	Very low	No sure	
Larbikrom	0.0	0.0	28.2	51.3	10.3	10.3	100.0
Banso	4.2	1.4	40.3	44.4	6.9	2.8	100.0
Akyem Akropong	0.0	4.1	34.2	41.1	15.1	5.5	100.0
Total	1.6	2.2	35.3	44.6	10.9	5.4	100.0

4.3.8 Factors perceived to have accounted for abundant ecosystem services

Whereas (53.3%) attributed the abundance of ecosystem services to high rainfall, and low deforestation, 19.9% said that high rainfall, low deforestation and low population were the major factors that have accounted for abundance of resources in the forest. Some (10.3%) were certain high rainfall was the single most important factor responsible the abundance of the benefits they derived from the forest. Finally, 10.8% of respondents thought that high rainfall, low deforestation and low use of agro-chemicals were responsible for high and abundant ecosystem services.

4.3.9 Factors that have accounted for decline in benefits from the reserve

Even though respondents seem to be split on the reasons for low ecosystem services, what was important was that 14.7% attributed the current low state of services provided by the forest to deforestation.

This was supported by participants in the focus group discussions held in the various communities. Throughout the discussions in all the communities, participants were sure that the major reason for diminishing ecosystem services nowadays is because of indiscriminate felling of trees in the forest.

4.4 Livelihood Activities generated by the people

4.4.1 Major livelihood activities in the area

From a list of activities provided for respondents to indicate which major one(s) they engage in; majority (80.4%) primarily engaged in farming activities, while 12.4% indicated they engage in multiple activities. For instance, some of the respondents were farmers, hunters, charcoal burners, and also gather firewood for sale.

Assessing how productive or otherwise of economic activities in the past, (81.5%) thought their activities were very productive, 13.0% indicated the activities were productive, and 2.2% were not sure of the state of their activity some 24 years ago. However, assessing the current state of their livelihood activities, (57%) assessed their output as normal, 14% indicated that the current state of their activities are unproductive while 23.4% could not decide (Figure 6).

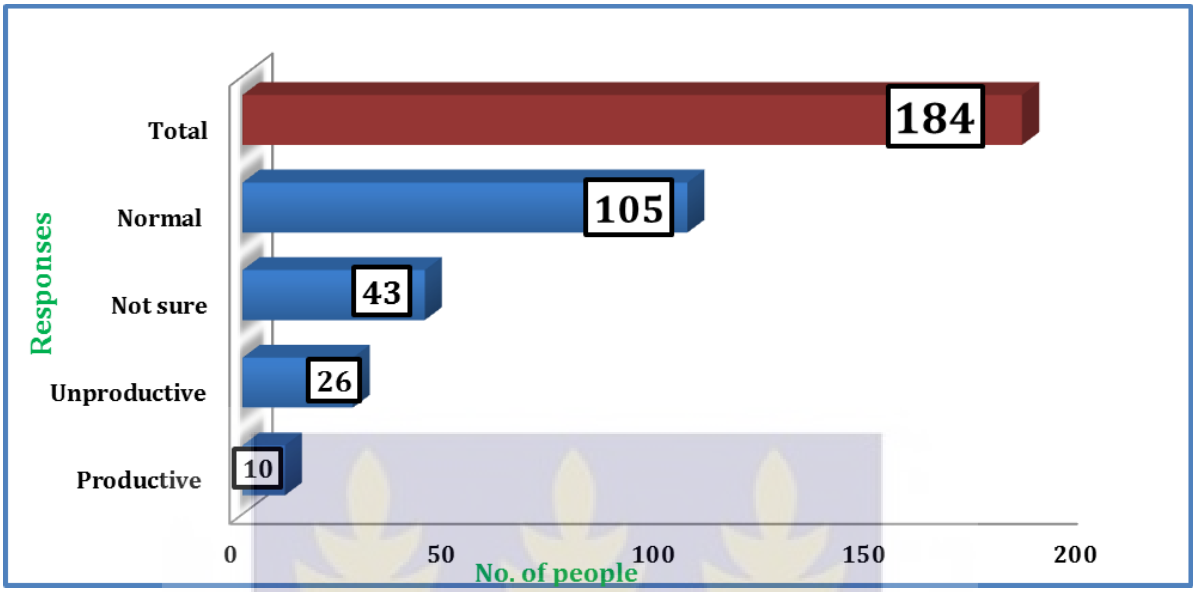


Figure 6: Respondents assessment of current state of livelihood activities

McNemar-Bowker Chi-square test (χ^2=164.333, df=6, p<0.05) indicates that opinions about previous state of their activity differs significantly from their current state of activity. This is clearly shown in Table 11, where the super-diagonal frequencies contain a larger sample than the sub-diagonal frequencies.

Table 8: Comparison of past and present state of livelihood activities

	Description	What is the current state of your activity?					Total
		very productive	productive	normal	unproductive	not sure	
What was the state of your activity some 20 years ago?	Very productive	3	1	68	72	5	149
	Productive	1	2	10	8	1	22
	Normal	0	0	2	1	1	4
	Unproductive	0	0	2	0	0	2
	Not sure	0	0	1	0	3	4
	Total	4	3	83	81	10	181

4.4.2 Reasons for productive Activities in the past

Reasons given by respondents for activities being very productive and productive were include high rainfall, good soil, dense forest, low population were assigned by respondents. Here 174 respondents indicated their reasons, out it (44.3%) indicated that their activities were flourished because of high rainfall, while (25.9%) thought that good soil at the time was responsible for the experience of high yield, whereas 18.4% said their activities were good because the forest was not disturbed much and therefore contributed to complex biogeochemical activities in the soil in particular. 11.4% raised varied points like low population, and the nonexistence of galamsey activities as the reasons for high yield in the past.

4.4.3 Reasons for decline in Activities in recent times

Reasons for decline in activities in recent times were deforestation, erratic rainfall, loss of soil fertility due to pressure on land; (31.5%) attributed their current situation to erratic rainfall and devegetation, while 14.7% blamed it on large scale deforestation that has been going on in the area over the past ten years, whereas (10.9%) gave erratic rainfall and increasing population as the reasons for the decline in their activities and (16.8%) raised different points as causing decline in their activities.

4.4.4 Sustainable practices

4.4.4.1 Sustainable farming practices

Forty-five respondents out of 164 identified mulching (*prɔka*) as a major practice which helps manage soil and soil conservation. During FGDs, participants also identified mulching as a major practice since it involves no financial burden and also help maintain soil water management. Forty-three respondents said that agrochemicals should not be abused and that correct quantity should be applied to ensure a balance of natural chemistry and man-made attempt to improve it. Thirty-seven proposed agro-forestry where farmers leave some trees on the farmland. Fire management on the farm especially during clearing of the land would help in reducing damage.

4.4.4.2 Sustainable logging practices

In all 21 respondents answered the question of sustainable lumbering. Out of the total responses 61.9% were of a strong conviction that controlled logging is a major practice which will ensure that trees would be available for future generations. During the FGDs participants also said that the forestry commission should guard the forest margins in order to reduce indiscriminate felling of trees, while (28.6%) believe that re-forestation and replacement of felled tree by state and the licensed chainsaw operators would be major sustainable practice while 9.5% opted for a combination of controlled logging and replacement of felled trees.

4.4.4.3 Sustainable hunting practices

Out of the total responses (72.7%) were of the view that to ensure animals in the forest are sustainably used, hunters should avoid the use of chemicals to kill animals. Whereas 27.3% said that hunters should avoid indiscriminate use of fire to catch animals. The Range Supervisor again said;

'Between August and December every year marked what they termed the close season for hunting since it this period that that the animals breed so hunting is restricted at this time frame.'

4.5. Effects of climate change on ecosystem services and livelihood outcomes

Table 9 shows test results of binary logistics regression to determine the effect of climate change on ecosystem services and livelihood outcomes. It was to ascertain the marginal effects of climate change variables such as temperature and rainfall on the ecosystem services and the livelihood outcomes based on the perceptions of respondents. At 1% significant level, respondents perceived there is a greater probability that reduction in rainfall will cause reduction in forest productivity (p=0.017), whilst at 5% significant level respondents perceived that livelihood outcomes will increase with good weather condition, and at 10% significant level respondents perceived that rainfall variability would lead to reduction in ecosystem services. Even though there was a relationship between amount of rainfall and forest productivity (0.437), low rainfall and reduction in water availability (0.854) it was not strong at 5% significant level.

Table 9: Effects of climate change on ecosystem and livelihood outcomes

	PARAMETERS	STANDARD ERROR	SIGNIFICANCE
Constant	1.538	1.068	0.149
Amount of Rainfall & forest productivity	0.080	0.437	0.854
Reduction in rainfall & reduction in Forest productivity	-1.162	0.645	0.017*
Reduction in forest productivity and reduction in ecosystem services	0.420	0.448	0.349
Rainfall variability and reduction in ecosystem services	0.673	0.399	0.092
Increase in livelihood outcomes and good weather	-0.834	0.403	0.038*
Secondary activities from the forest	-0.175	0.535	0.743
Low rainfall and Reduction in water generation	0.247	0.445	0.579

**, represents 5% significant levels respectively. F-statistic 3.089 Prob> F 0.000 R-squared = 0.069 Adjusted R-squared = 0.103 observations 184 -2 Log likelihood = 191.514*

4.5.1 Effects of low rainfall on communities

In evaluating the likely implication (s) of low and variable rainfall on communities, 111 respondents representing 60.3% said that with disrupted rainfall, crop yield would reduce. Moreover, 33.7% said that crop yield will reduce and water availability and quality may also be affected negatively.

4.6. Adaptation measures communities are adopting to reduce vulnerability against climate change

Respondents were asked a direct question, whether they were ready to meet any future challenge posed by the changing weather events, (46.2%) said yes, while (44.6%) said no and 9.2% were undecided.

With regards to adaptation measures being undertaken (23.4%) said they now planting late to meet the late onset of rain while (25.0%) indicated that they were going into trading alongside farming and another (25.0%) said that they will wish to migrate to big towns where better prospects are available. Other adaptation measures by respondents are mulching (18.5%) and agroforestry (8.2%).

4.6.1 Determinant of vulnerability to climate change and variability

A binary logistic regression to determine respondents' vulnerability levels relative to climate change is presented in (Table 10). Factors used as a measure of vulnerability were access to credit, age, educational level, temperature perception, alternative livelihood programme, gender, rainfall perception, total asset and climate change awareness measured at 5% significant levels. Respondents perceived temperature as a factor that will influence their adaptation measures to reduce their vulnerability to climate change (p=0.039). Age and total asset were factors that also influenced adaptation strategies to reduce their vulnerability against climate change. Alternative livelihoods programmes were also perceived by respondents as major factor that influence adaptation and therefore can determine vulnerability (p=0.041) of a group or persons. This was statistically significant at 5% significant level. Even though the other factors education level, gender and climate change awareness were significantly low at 5%, there was a relationship which was a weak one.

Table 10: Determinant of vulnerability

	PARAMETERS	STANDARD ERROR	SIGNIFICANCE
Constant	1.999	1.091	0.067
Age	-0.025	0.013	0.061
Educational level	-0.343	0.375	0.361
Temp. perception	0.801	0.387	0.039*
Alt. livelihood prog.	0.111	0.363	0.041*
Gender	-0.391	0.361	0.279
Rainfall perception	0.103	0.381	0.788
Climate change awareness	-0.618	0.435	0.155

**, represents 5% significant levels respectively, F-statistic 2.680 Prob> F 0.000 R-squared = 0.088 Adjusted R-squared = 0.128 observations 184 -2 Log likelihood = 198.238*

CHAPTER FIVE

DISCUSSION

5.1 Climate change

The views of local communities about the ongoing changes in climate, its causes and impacts can be entirely different from what science has explained about climate change (Maharjan and Joshi, 2013). The views of these community members therefore help build informed opinions about the level of understanding of rural people on climate change which eventually influences policy. Maharjan and Joshi, (2013) have observed that although climate change is a universal phenomenon, its indicators and manifestations are entirely local, so are the adaptation choices, strategies, and practices. There is therefore the need to emphasise on a bottom-up approach in climate change studies since it is at the local level where adaptations ultimately take place (Smit and Wandel 2006).

Climate change as it manifests in changing weather patterns especially in rainfall variability, high temperatures, drought, and strong winds is important global issue that is a concern to global leaders, and ecologists alike. Respondents showed in-depth knowledge and understanding of the changing climatic pattern through the answers they provided in both the survey and the focus group discussions. Regardless of sex, education and community one came from, they perceived the concept in the same way ($X^2 = 9.67$, df = 11, p >0.05).

For instance, finding association between sex of respondents and their perception about climate change, showed that there was no evidence that both men and women in the study area perceive climate change differently and so what came to mind when they hear about climate change is the same across sexes (χ^2=9.673, df=11, p>0.05).

What is significant here was that majority of respondents were sure that the principal cause of changing climatic events is attributable to human induced factors primarily deforestation and farming (Figure 4). This confirms various reports and articles on climate change which attribute the current global warming to human induced causes (IPCC, 2007b; AGU, 2013).

The survey results also indicate that rainfall in the area has not been regular and frequent recently as it was some decades ago. Irregularity and reduction in amount of rain the area received in recent years were likewise identified by respondents in the FGDs. Views expressed when they were asked about their perception on temperature showed increasing temperatures in the area (Appendix 3). Data obtained from the GMet which shows a downward trend in rainfall in the area since 1961 and an upward trend in temperature records in the area since 1971 confirms respondents' perception.

The general decline in rainfall and increasing temperatures (figures 2 and 3) in the area over the decades has been observed by respondents. Through the survey and the FGDs, it was found that rainfall has reduced now relative to past levels and this corroborated very well with the scientific data from the GMet. This observation can be interpreted to mean that because of rapid deforestation that had occurred in the area in recent times, forests role in the water cycle has reduced thus low and variable rainfall.

Respondents further identified some adverse effects of changing climate as wind storms that have been hitting the area particularly Banso in recent years. As noted by Sedjo (1991), extreme events associated with climate change, such as windstorms, could put even healthy forests and human societies at risk. Some forest-replacing events, however, could facilitate the transition to a newer, better-adapted forest, since these wind storms being experienced is as results of the deforestation as noted by the people during the various FGDs held.

5.2.1 Importance of vegetation in moderating local climate

A study carried out by Brovkin (2002) suggested that climate exerts the dominant control on spatial distribution of the major vegetation types on a global scale. In turn, vegetation cover affects climate via alteration of the physical characteristics of the land surface like albedo, roughness, water conductivity (biogeophysical mechanisms) and atmospheric gas composition, such as, CO_2 and CH_4 (biogeochemical effects) (Brovkin, 2002). This connection between climate and vegetation has always been clear and unambiguous. It is even sometimes difficult to explain which one affects the other, that is, whether climate of an area determines the nature of vegetation or whether the vegetation of an area determines the kind of climate the place should have. It's indeed like a chicken and egg dilemma.

From the results, it was obvious that the people in the area understood very well the link between vegetation and climate even though they could not tell the complex biogeochemical interaction in its technical terms. During the FGDs, they were able to mention how vegetation affects climate through rainfall, temperature moderation and serving as wind breaks.

What is important here was that there was a general agreement by respondents that vegetation cover especially forest ecosystem plays a crucial role in both weather and climate of an area and that this critical role played by plants may be both at the local or global level. Other crucial role played by plants in balancing global climate through carbon sequestration and thus reducing global warming is worth mentioning.

5.2 Ecosystem services provided by the Atiwa Range Forest

Ecosystem services support the well-being of humanity on earth (IUCN, 2008). Respondents showed in-depth understanding of the usefulness of the reserve in both direct and indirect ways; tangible and intangible benefits provided by the reserve. Among the tangibles they identified, were non-timber forest products (examples snail, mushrooms, honey, mortar and pestle) which they use and encounter most often. The forest also helps maintain air and water quality, wind-break, reduce landslides and floods, and play a key role in stabilizing climate which are in line with the (MA, 2007).

Proper functioning biodiversity provides good and quality services that are wholesome to human well-being (Díaz *et al.* 2005, Kremen 2005). Changes in the species richness, abundance, and composition of an ecosystem may lead to parallel changes in the amount or quality of services provided by that ecosystem, including carbon sequestration (Bunker *et al.* 2005), pollination (Ricketts 2004), or pest control (Phillpott *et al.* 2009), that are indicative of a linear relationship between biodiversity and ecosystem services (Schwartz *et al.* 2000). Human activities however, continue to put strain on natural resources the world over (MA, 2005).

Over the past 20 years, the Atiwa Range Forest Reserve has experienced its own share of human induced pressures. In order to better understand the benefits fringe communities derive from the reserve and to see whether these services are increasing or decreasing over time, remote sensing data was used to track the changes that the forest has undergone over the past few decades. It was found that, land use changes around and the reserve has the potential of degrading the proper functioning of the forest and thus its capacity to provide both local and global services.

The ARFR has seen a continuous decline since 1991 (Table 6). As primary forests continue to decrease to pave way for secondary forests due largely to human activities such as farming, settlement and roads, the dynamics of the area, the quadruple benefits of forest (addressing climate change challenge, providing ecosystem services, livelihood generation and biodiversity preservation) also reduce. In other words, as secondary forest increases, primary forests decrease and subsequently ecosystem services and reduction in the livelihoods derived from the forest are also affected. The continuous depletion of the forest as shown by the RS information (Figure 4a, b and c) attesting to the wide belief in the area that the reserve is depleting at a fast rate. The period between 2002 and 2013 saw unprecedented human activity in the area leading to the rapid depleting of the forest cover of the area.

It was not surprising that the three communities through the answers they gave in the survey and the FGDs, were emphatic that the ecosystem services they were getting from the reserve both tangibles (snail, mushrooms, honey products) and intangibles (rainfall, wind breaks, water quality) have all reduced relative to what they were getting some 20 years ago.

For instance, wind storm which used to be rare in the area especially at Banso due largely the thick vegetation cover as a results of the sacred grove, is becoming a great concern now according to the locals. During the focus group discussions, the Banso group expressed concerns about this new phenomenon which also makes them vulnerable. One of them said that,

'Even last month (June 2014), there was a turbulent wind storm which ripped off the roofs of some buildings. We are therefore not certain what future storms will do in this community and how are to combat that. This causes vulnerability in the face of climate change where wind storms and extreme events are predicted to increase.'

When they were asked to give reason(s) for the storms they were unanimous and unequivocal, and a woman burst out,

'Before those large trees were cut (around the sacred grove) some ten years ago, we never experienced these storms and now after they were cut we are unsafe from these wind storms. You do not need any one to tell you they are the cause.'

This point was also stressed by the Range Commander of the Anyinam portion of the reserve. According to him,

'One important functions of vegetation (trees) is that it is able to protect towns form the damaging impact of wild winds and once you do not take good care of these trees and they are felled, you expose building to the rage of winds.'

Throughout the FGDs, participants in all the communities said that rainfall has also reduced. For instance during the Larbikrom a participant said;

'Nowadays, it does not rain as it was in the past i.e. over ten years ago. And what we have seen is that it sometimes rain heavily in the forest but only drizzles here in this community. This especially has made some of the resources (snail, mushrooms) we were getting from the forest drastically reduced.'

5.3 Major livelihood Activities in the area

Many rural people across the world derive their livelihood from the natural environment. Among the principal livelihoods generated from the forest environment are farming, hunting and logging. Fringe communities along the ARFR generate a number of economic activities; faring, chainsaw activities, firewood fetching, snail collecting, hunting etc. The results of the survey which showed over 75% of the people engaged in farming is above the national average of 73.5% of rural agriculture population (Awusabo-Asare *et al.* 2013).

Very few of the people said they engaged in hunting and logging. The reason why very few people said they engaged in hunting and logging is probably because the forest is a protected area and these activities meant entering the core area which is prohibited. People who enter the reserve to undertake any illegal activities may not say it for fear of being arrested. Another likely interpretation may be that because people generate varied livelihoods from the forest, they are more comfortable to mention farming than other activity.

Respondents were certain that the state of their activities in the past were more productive and profitable than they were today. Using the McNemar-Bowker test of symmetry to find how consistent respondents were in their opinion regarding their state of their livelihood in the past and now, the chi-square results of $P\ (0.000) < \alpha\ (0.05)$ *with a* $\chi^2 = 164.333$ *and* $df = 9$ showed significant results meaning respondents' opinions varied considerably in comparing their livelihood now and 20 or so years ago.

According to locals livelihood outcomes in the area are becoming less profitable largely due to the depletion of the reserve and also the general changing patterns of the weather. They further said that decreasing and irregular rainfall currently being experienced compared to levels decades ago is largely responsible for the low livelihood outcomes. They further perceived decreasing soil quality, pressure on resources due to increasing population as other reasons responsible for the low trends in livelihoods.

In this era of declining livelihoods sustainable practices become central to forest management and rural livelihood schemes. Essential sustainable livelihood practices proposed by respondents were mulching, mixed cropping, agroforestry, correct application of fertilizers and other chemicals, and fire management on farmlands. Sustainable logging and hunting practices mentioned included controlled logging, replacement of felled trees and discouraging the use of chemicals to hunt, avoiding the use of fire to trap animals, avoiding killing of young animals during hunting. All these are practices that could help maintain the biodiversity of the area and reduce the vulnerability among the fringe communities.

5.4 Effects of climate change on ecosystem services and its impacts on Livelihood outcomes

According to Sedjo (2010; 1993), both temperature and the amount and pattern of precipitation are critical to forests growth. In general, warmer and wetter conditions will enhance forest growth, while warmer and drier conditions will likely be detrimental to forest growth. If drying is significant, grasses will often replace forests in natural systems.

Respondents showed ample understanding of this rainfall-forest relationship. The results of regression test showed how respondents perceived climate change effects on ecosystem services and its likely impacts on livelihoods. The study showed a positive relationship between reduction in rainfall and reduction in forest productivity. This is because, as the amount of rainfall increases, the productivity from the forest is also expected to increase unless in situations where the rainfall intensity or amount increases to the extent that some of the life in the forest cannot survive.

This variable was highly statistically significant at 5% significant level with significant figure (p=0.017) and the coefficient from the analysis was -1.162. This implies that, as rainfall reduces by 1mm the log of odds of the reduction in forest productivity reduces by 1.162. This is due to the fact that reduction in rainfall makes the survival of certain species in the forest goes extinct which the repercussion of the effect is felt by the respondents.

In focus group discussions held as well as elite interviews, this point was made in several ways to suggest that the rainfall element of climate is very phenomenal in influencing the ecosystem services livelihoods of community members. One of the respondents during a focus group discussion expressed bitterly that:

"Some years ago, my people would not go far and their baskets would be full with edible products and their soup would be more delicious…. But today, the value of the forest to provide these things cannot be said here, you can search deep and cannot even pick one snail, they have all vanished"

This study further revealed a positive relationship between increase in livelihood outcomes and good weather pattern. As good weather prevails the adverse effect of climate change on climate dependent activities are reduced which then improves the standard of living of the respondents. This variable was statistically significant at 5% with ($p=0.038$) and the coefficient from the analysis was -0.834. This implies that the standard of living of the respondents increases with good weather.

Respondents were emphatic during the FGDs that livelihood outcomes have reduced recently, with temperature and rainfall figures showing weather variability. One can confidently say that respondents' perception of good weather with increased livelihood outcome was confirmed.

In the interviews with stakeholders and opinion leaders, it was established that reduced rainfall levels have caused gradual decrease in the ability of the forest to provide livelihood support system as it used to be the case. A traditional ruler during the FGDs explained that;

"Because the rains have not been reliable, our farms sometimes become affected especially if you sow the seeds and it does not rain it leads to low yield and losses; the poor rainfall pattern has also driven away the crabs, mushrooms, snails among others which we picked for free some decades ago".

This position was given support during the focus group discussions when especially old men and women who have been farmers for very long time gave varied accounts and expressed frustrations about the continuous reduction of forest resources as a result of the decreasing rainfall patterns.

These perceptions by respondents of decreasing and variable rainfall were corroborated by the rainfall data obtained from the Ghana Meteorological Agency (Figure 2) which shows a declining rainfall pattern of the study area. In the survey, it was unanimous that the reducing rainfall pattern has affected the livelihood support they used to derive from the forest.

Moreover, as the productivity from the forest reduces, there will be less resources or shelter to accommodate its populations. The findings from the various elite interviews and FGDs supported the claim that as the productivity of the forest declined, the ecosystem support mechanism or function also decreases. This point was succinctly made by a key personality at the Forestry Commission who explained:

"The illegal activities of chain saw operators mostly cut down the trees thereby getting rid of the canopies; poor rainfall and increasing temperatures cause unfavorable environment for living organisms living in the forest which in the end destroys the habitats"

It also came up that there were other human activities that that have over the years contributed to the decline of the NTFPs. Throughout the interviews and the discussions the people identified the unguarded use of agrochemicals which was causing great havoc in the area as another important factor accounting for the reduction in non-timber forest products in recent times. A from Larbikrom said,

'The use of extensive weedicide both in the farms and the backyards to control weeds has also led to the vanishing of snails, and mushroom growth, and the disappearance of some crops species like taro (Colocasia esculenta).'

5.5 Adaptation measures communities are adopting to reduce their vulnerability to climate change

According to Maharjan, and Joshi, (2013) adaptation issues are crucial especially for the vulnerable communities who are more affected by the adverse impacts of climate change. For such communities, how they perceive the ongoing changes determines how they formulate strategies to cope with the changes in the short run and to adapt to the long term changes. In other words, it is necessary to realize that some changes are going on in order to take actions to adjust to those changes (Deressa *et al.* 2011). Thus this objective was to ascertain the readiness of the people in the area to deal with climate change. Among the factors that determined ones vulnerability, temperature perception and the lack of alternative livelihood programmes were the major factors respondents perceived important.

The temperature perception was statistically significant at 5% with (p=0.039) and the coefficient from the analysis was 0.801. This implies that as the individual perceives changes in temperature the log of odd of the individual not being vulnerable to climate change increases by 0.801 holding all other factors fixed. This result is consistent with the *apriori* expectation which indicated that as an individual perceives changes in temperature, the greater the individual adapt a strategy and so renders him/her not vulnerable.

The results from both the survey and the focus group discussions and the climatic data obtained from the GMet, point to a gradual increase in temperature of the area. It therefore makes sense that people in the area are preparing themselves to meet the challenge. That was why when respondents were asked to mention some sustainability practices mulching, and agroforestry were identified by them. These practices ensure that the soil is kept moist for farming activities to continue without causing serious damage to the environment.

The lack alternative livelihood programmes were not statistically significant at 5% with (p=0.041) and the coefficient from the analysis was 0.111. For any rural community to reduce their vulnerability against the adverse impact of climate change, livelihood diversification at the rural area is the surest way to go. However, alternative livelihood programmes in this area is virtually non-existent and so the people here were not expectant and might have thought that no one would even bring it at all. Even though they perceived availability of such programmes as a way of reducing peoples vulnerability against the climate change challenge.

According to (Knowler and Bradshaw, 2007), the adoption of agricultural technologies requires sufficient financial well- being and so an individual with alternative livelihood programme leading to the engagement in other livelihood activities that are not climate change dependent will equip her/his financial standing which facilitate the adoption of strategies and so render him/her less vulnerable to climate change.

The perception local people about rainfall and building capacity to deal with climate variability are crucial for rural people's empowerment. This helps them to adopt adaptation strategies. Even though data obtained from the GMet indicate a downward rainfall trend, it is so marginal that respondents felt rainfall had not reduced to the levels where they could make them vulnerable. This result may be partly due to the time in which the data was collected (July 2015) which marks the peak of the rainy season of the area as a result respondents might have forgotten about the years of variability.

The age was not statistically significant at 5% with (p=0.061) and the coefficient from the analysis was -0.025. The issue of age and vulnerability is not a straight forward relationship, because dependent population anywhere is generally more vulnerable than active population. Thus, as one grows from childhood to adulthood they become less vulnerable but upon reaching old age (above 60 years in Ghana) they become vulnerable again. Again age and vulnerability is dependent on one's wealth and asset. The less wealthy and older person is the more vulnerable they are to climate change impact and vice versa. From the study majority of respondents were within the active population bracket (18 to 60 years), thus giving rise to the positive relationship between age and vulnerability.

Another important determinant of vulnerability is education level of the individual. Higher level of education is believed to be associated with access to information on improved technologies and productivity consequences (Norris and Bati, 1987). Evidence from various sources indicates that there is a positive relationship between the education level of the household head and the adoption of improved technologies (Igoden *et al.*, 1990; Lin, 1991) and not being vulnerable to climate change (Maddison, 2006). Therefore, an individual with higher levels of education are more likely to better adapt to climate change and so make them less vulnerable.

Education showed a weak relationship (at 5% significant level) with vulnerability to climate change largely because the educational profile of respondents was a little higher with over 90% receiving formal education (even though very few had pursue education above secondary level). This means that even though higher educational level corresponds to less vulnerability, because respondents could generally understand the phenomenon and its effects, education was not a major determinant of vulnerability in the area.

Gender issues are very central to the climate change debate and more importantly susceptibility of females and males. Male-headed households are often considered to be more likely to get information about new technologies and take risky businesses than female-headed households (Asfaw and Admassie, 2004) and so help males to be less vulnerable to climate change than their female counterpart. Moreover, Tenge *et al.* (2004) argued that female- headed households may have negative effects on the adoption of soil and water conservation measures because they have limited access to information, land and other resources due to traditional social barriers.

The result of Nhemachena and Hassan (2007) study indicated a contrary result to the above argument by showing that female-headed households are more likely to take up climate change adaptation methods. This study follows the later argument that indicates that male-headed households are more likely to take up adaptation methods as they have more access to resources and information. Moreover, females are thought to be closer to the natural environment than their male counterpart thus, they are able to detect early environmental changes especially climate change.

The results of the study indicate that gender is not a major determinant of the vulnerability in the area. The reason for this non-significant result is that the study area forms part of the larger Akan society in Ghana where inheritance system is the matrilineal. Hence, women are treated in an almost equal way in terms of control and ownership of resources in these communities. That is access to and control of resources in the Atiwa area between men and women are almost the same.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusions

Based on the results from the study it was found that, the range provides many ecosystem services; both tangible and intangible benefits to the people and the physical environment. These include snails, mushrooms, honey, herbal medicine, mortar and pestle; and rainfall, temperature moderation, wind breaks, cultural heritage, and water. Due to increasing temperatures and variable rainfall being experienced in the area in recent times, these ecosystem goods and services (provisioning, regulatory and supporting services) are reducing and thus attention should be paid to this worrying trend before a tipping point is reached.

Secondly, the livelihoods fringe communities generate mainly agricultural support, logging, and hunting activities have all helped increase the well-being of people in these communities. The study, however, concludes that the forms of support provided has reduced over time mainly as a result of erratic rainfall, devegetation, depleting soil fertility, and mining operations.

Moreover, climate change and its effects on ecosystem services and livelihood outcomes are very well understood by respondents. This was indicative by both the tests conducted to measure respondents' perception about climate change and the determinant of vulnerability.

The study concludes that the changing climate has forced the community members to adopt various coping mechanisms including late cultivation of crops in the main cropping period; complementing the traditional farming activities with trading and so on. Finally, the local people though mostly illiterate, do have adequate understanding of changing climatic patterns and effect on their economic and social lives; they do also have understanding on how to adapt and cope with these stressor.

6.2 Recommendations

Based on the findings of this work, the following recommendations are proposed;

There should be an enforcement of forest regulations to prevent encroachment into the forest. It was found out that even though ARFR is earmarked for preservation, there were evidence of continuous human activities which over the past decade is causing fast depletion of the forest and was supported by the remote sensing data obtained for the work. This therefore calls for robust enforcement of the regulation setting aside the reserve as a biodiversity conservation zone.

Secondly, in order to ensure active community participation in protecting the reserve for fringe communities to derive livelihoods there has to be an involvement of traditional authorities and community members in the protection of forest reserves and the regulatory functions. There has to be a strong collaboration between the Forestry Commission and local especially through their chiefs to ward off any illegal extraction of the timber products and limited entry for other bush meat.

Finally, there should be efforts aimed at enhancing and equipping the community members in alternate livelihood mechanisms to mitigate the adverse effect of changing climate patterns and to build their adaptive capacity.

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APPENDICES

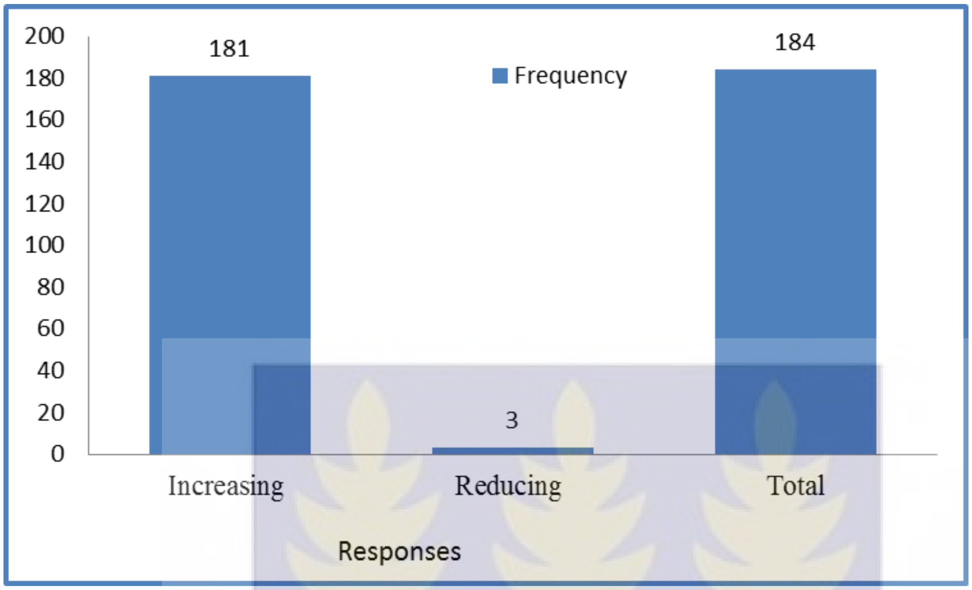
Appendix 1a: Change detection of the ARFR from 1991-2002

	INITIAL										
	Area (in hectares/ %)	Bareground_1991.shp		Vegetation_1991.shp		Forest_1991.shp		Row Total		Class Total	
		Ha	%	ha	%	ha	%	ha	%	ha	%
FINAL	Bareground2002.shp	1909.89	44.07	2036.07	3.58	62.28	0.19	4008.24	100	4008.24	100
	Vegetation_2002.shp	2380.95	54.94	50105.61	88.01	8510.22	25.54	60996.78	100	60996.78	100
	Forest_2002.shp	43.2	0.99	4792.95	8.42	24753.51	74.28	29589.66	100	29589.66	100
	Class Total	4334.04	100	56934.63	100	33326.01	100		0		0
	Class Changes	2424.15	55.933	6829.02	11.994	8572.5	25.723		0		0
	Image Difference	-325.8	-7.517	4062.15	7.135	-3736.35	-11.212		0		0

Appendix 1b: Change detection of the ARFR from 2003-2012

	INITIAL										
	Area (hectares/%)	Bareground_2002.shp		Vegetation_2002.shp		Forest_2002.shp		Row Total		Class Total	
		Ha	%	ha	%	ha	%	ha	%	ha	%
	Bareground2013.shp	3206.07	79.99	4709.97	7.722	549.81	1.858	8465.85	100	8465.85	100
FINAL	Vegetation_2013.shp	798.84	19.93	53993.79	88.519	7696.89	26.012	62489.52	100	62489.52	100
	Forest_2013.shp	3.33	0.08	2293.02	3.759	21342.96	72.13	23639.31	100	23639.31	100
	Class Total	4008.24	100	60996.78	100	29589.66	100	0	0	0	0
	Class Changes	802.17	20.013	7002.99	11.481	8246.7	27.87	0	0	0	0
	Image Difference	4457.61	111.21	1492.74	2.45	-5950.35	-20.11	0	0	0	0

Appendix 2



Respondents' perception on current trends of temperature in the area

Appendix 3

Summary of explanatory variables

Variable	Description	Mode of measurement	Expected sign
Y_i	Climate change effect perception	Dummied: 1 = Effect 0 = No effect	
$RAIN_{FP}$	Amount of Rainfall & forest productivity	Dummied: 1 = Yes 0 = No	+
$R_{RAIN\&Fp}$	Reduction in rainfall & reduction in Forest productivity	Dummied: 1 = Yes 0 = No	+
$R_{FP\&RECO}$	Reduction in forest productivity and reduction in ecosystem services	Dummied: 1 = Yes 0 = No	+
$RAIN_{VAR\&ECO}$	Rainfall variability and reduction in ecosystem	Dummied 1 = Yes 0 = No	+
$LIVE_{WEA}$	Increase in livelihood outcomes and good weather	Dummied: 1 = Yes 0 = No	+
SEC_{FA}	Secondary activities from the forest	Dummied: 1 =Yes 0 = No	-
RED_{GE}	Reduction in water generation	Dummied: 1 = Yes 0 = No	+

Appendix 4

Summary of explanatory variables

Variable	Description	Mode of measurement	Expected sign
Y_i	Vulnerability	Dummied: not vulnerable =1 vulnerable = 0	
Ag_e	Age	Years	+/-
E_{du}	Educational level	0 = No Formal educ. 1 = Formal educ.	+
$Temp_p$	Temp. perception	0 = Unpredicted 1= decreasing 2 = increasing	+
Alt_l	Alt. livelihood prog.	Dummied: Yes=1 No =0	+
Gen	Gender	Dummied: 1 = Male 0 = Female	+/-
$Rain_p$	Rainfall perception	0 = Unpredicted 1 = Decreasing 2 = Increasing	+
$Asset_t$	Total asset	Ghana Cedis	+
Awa	Climate change awareness	Dumm ied: 1 = Yes 0 = No	+

Appendix 5: Questionnaire

This questionnaire administration is in partial fulfillment of my Post-Graduate Degree in Climate Change and Sustainable Development (MPhil) Programme on the above topic from the University of Ghana, Legon. Your involvement in the project (thesis) will be deeply appreciated and any information given will be treated in strict confidentiality in order not to betray research ethics and good practices. Kindly answer the questions by ***ticking [√]*** option(s) that best suit(s) your understanding.

A. PERSONAL INFORMATION

1. What is your Sex?

1	Male	[ ]
2	Female	[ ]

2. How old are you?

3. What is your occupation?

1. Farming	[ ]	5. Logging	[ ]
2. Hunting	[ ]	6. Carpentry	[ ]
3. Trading	[ ]	7. Galamsey	[ ]
4.Herbal Specialist	[ ]	8. Any other, please specify	[ ]…………………..….

4. What is your level of education?

1. Basic	[ ]	4. Tertiary	[ ]
2. Elementary	[ ]	5. Any other please specify	[ ] ……………………
3. Secondary	[ ]		

6. What is the name of your community?

B. KNOWLEDGE ABOUT CLIMATE CHANGE

1. Have you ever heard about climate change?

1. Yes [ ]	3. Not sure [ ]
2. No [ ]	

2. If yes, where did you first hear it?

1. On radio [ ]	5. Local information service [ ]
2. On TV [ ]	6. A state organized forum [ ]
3. Agriculture extension officer [ ]	7. Newspapers [ ]
4. District information service [ ]	8. Any other platform, please specify [ ] ………………

3. Anytime you hear about climate change, what comes to your mind? ***(You can choose more than one option)***

1. Intense sunshine [ ]	5. Rainfall variability [ ]
2. High temperatures [ ]	6. Wind storm [ ]
3. Prolonged dry season [ ]	7. Any other please specify [ ] ……………………
4. Frequent flooding [ ]	

4. Do you have any idea what the causes of climate change?

1. Yes [ ]	3. Not sure [ ]
2. No [ ]	

5. If yes, what do you think cause(s) climate change? ***(You may choose more than one option)***

1.Cutting off trees [ ]	4. Charcoal burning [ ]
2. Bush burning [ ]	5. Use of agro-chemical [ ]
3. Mining [ ]	6. Any other please specify [ ] ……………………...

6. What has been the pattern of rainfall in recent past?

1. Regular [ ]	3. Not sure [ ]
2.Irregular [ ]	

7. What has been the recent pattern of rainfall?

1. Regular [ ]	3. Not sure [ ]
2.Irregular [ ]	

8. How would you describe rainfall levels of this area in the recent past (10-20 years ago)?

1. Normal [ ]	5. Very low [ ]
2. Variable [ ]	6. Not sure [ ]
3. Very high [ ]	7. Any other, please specify [ ] ………………………..
4. Low [ ]	

9. How would you describe recent rainfall levels in this area?

1. Normal [ ]	5. Very low [ ]
2. Variable [ ]	6. Not sure [ ]
3. Very high [ ]	7. Any other, please specify [ ] ………………………..
4. Low [ ]	

10. How will you describe current temperatures of the area?

1. High [ ]	2. Low [ ]

11. Does vegetation (plant cover) help in moderating the local weather/climate?

1. Yes [ ]	3. Not sure [ ]
2. No [ ]	

12. If yes, how? ***(Please choose more than one if necessary)***

1. Plants provide shade	[ ]
2. Vegetation aids in water cycle which moderates micro-climate	[ ]
3. Vegetation cover stabilizes daily temperatures	[ ]
4. Any other kindly specify [ ] …………………………………………………………………………	

C. KEY ECOSYSTEM SERVICES FRINGE COMMUNITIES DERIVE FROM THE RESERVE

1. Is the forest accessible to community members?

1. Yes [ ]	3. Not sure [ ]
2. No [ ]	

2. If no why?

3. What are some of the tangible or physical benefits/products you get from the forest?

4. What was the state of these benefits some ten or more years ago?

1. Abundant [ ]	5. Very low [ ]
2. High [ ]	6. Not sure [ ]
3. Moderate [ ]	7. Any other, please specify [ ]…………….
4. Low [ ]	

5. If abundant, what do you think might have accounted for their abundance? ***(You may choose more than one option)***

1. High rainfall	4. Any other, please specify [ ] ………………
2. Low deforestation	
3. Afforestation programme	

6. What is the state of these benefits now or in recent times?

1. Abundant [ ]	5. Very low [ ]
2. High [ ]	6. Not sure [ ]
3. Moderate [ ]	7. Any other, please specify [ ] ………….……….
4. Low [ ]	

7. If low, what do you think may have accounted for this? ***(You may choose more than one option)***

1. Low rainfall [ ]	6. Deforestation [ ]
2. Variable rainfall [ ]	7. Agriculture [ ]
3. High sunshine [ ]	8. Mining [ ]
4. High temperatures [ ]	9. All of the above [ ]…………………………..
5. Use of chemicals [ ]	

8. What are some of the intangibles the community gets from the forest? ***(Please choose more than one option)***

1. Waste assimilation [ ]	4. Temperature regulation/moderation [ ]
2. Water purification [ ]	5. Cultural heritage site [ ]
3. Aids in rainfall [ ]	6. Any other, please specify [ ] ……………………

9. What kind of socio-cultural benefits does the forest serve to your community? ***(You may choose more than one option)***

1. Burial site [ ]	4. Eco-tourism [ ]
2. Sacred grove [ ]	5. Educational purposes [ ]
3. Archaeological site [ ]	6. Any other please specify [ ] ………………………..
4.Environmenatal aesthetics [ ]	

C i. Effects Of Other Human Activities On The Reserve And On Ecosystem Goods And Services

There are recent talks about exploration activities for bauxite in the forest. Kindly answer the following questions on the above subject by ticking options that best suits your understanding.

10. Are you aware there are large deposits of bauxite in the reserve?

1. Yes	[ ]	3. Not sure	[ ]
2. No	[ ]		

11. Should the bauxite be mined taking into consideration the environmental cost to the area?

1. Yes	[ ]	3. Not sure	[ ]
2. No	[ ]		

12. If yes, briefly state your reason(s).

13. If it should not be mined, kindly state your reason(s).

For the past six years, there has been a spate of illegal small-scale gold mining activities (galamsey) in the area.

14. Should this activity continue considering the environmental cost to the area?

1. Yes	[ ]	3. Not sure	[ ]
2. No	[ ]		

15. Which product(s)/resource(s) from the forest have been severely affected by the galamsey activities? ***(You may choose more than one option)***

1. water/rivers [ ]	4. plant species [ ]
2. soil [ ]	5. wild animals [ ]
3. land [ ]	3. Any other, please specify [ ] ……………………..

D. LIVELIHOODS OPTIONS COMMUNITIES DERIVE FROM THE RESERVE.

1. What kinds of activity do you engage in the forest?

1. Lumbering [ ]	6. honey extraction [ ]
2. Agriculture [ ]	7. Any other please specify [ ] …………………
3. Hunting and gathering [ ]	
4. Gathering of firewood [ ]	
5. Charcoal burning [ ]	

2. What was the state of your activity some 20 or so years ago?

1. Very productive [ ]	5. Not sure [ ]
2. Productive [ ]	6. If any, please state [ ] ……………………
3. Normal [ ]	
4. Unproductive [ ]	

3. If very productive or productive, kindly state what might have accounted for that?

4. What is the current state of your activity?

1. Very productive [ ]	5. Not sure [ ]
2. Productive [ ]	6. If any, please state [ ] ……………………

3. Normal [ ] 4. Unproductive [ ]	

5. If normal or unproductive now, what has accounted for the situation? ***(You may choose more than one option)***

1. Low rainfall [ ]	4. De-vegetation [ ]
2. Erratic rainfall [ ]	5. Depleting soil fertility [ ]
3.Mining activities [ ]	6. Any other please specify [ ] …………………...

6. What are some of the best practice(s) you will adopt in your activity for you and future generations to continue to benefit from the forest? ***(For those who engage in agriculture, lumbering, charcoal burning and hunting only)***

Agriculture ………………………………………………………………………………………………
Lumbering …………………………..…………………………………………………………………
Hunting and gathering ……..………………………………………………………………………………………

E. RELATIONSHIP BETWEEN CLIMATE CHANGE EFFECTS ON ECOSYSTEM SERVICES AND LIVELIHOODS OUTCOMES IN FRINGE COMMUNITIES ALONG THE RESERVE.

Questions 1 to 7 are measures of respondents' perception on effects of climate change on ecosystem services and livelihood. Choose the option by checking the either yes or no.

		Yes	No
1.	There is a link between amount of rainfall received and forest productivity		
2.	Forest productivity will drastically reduce with reduction in average rainfall/ or decreased rainfall pattern		
3.	Reduction in forest productivity will causes reduction in ecosystem services		

4.	There is a connection between rainfall variability and reduction in ecosystem services (i.e. the benefits communities get from the forest)		
5.	There has been an increase in livelihood outcomes recently due to good weather		
6.	People get secondary activities (jobs) from the forest		
7.	Water generation has decreased recently due to poor rainfall in recent times		

8. What is/are the likely implication(s) low and variable rainfall will have on the benefits communities get from the forest?

1. Increased pollution [ ]	4. Reduction in water availability [ ]
2. Effects on water quality in the area [ ]	5. Any other, kindly specify [ ]………………… …………………
3. Reduction in crop yield [ ]	

9. Which of the following activities as far as you are concerned, is causing rapid destruction to the forest and ultimately the ecosystems services? ***(You may choose more than one option)***

1.Small scale mining/ galamsey [ ]	5. Settlement [ ]
2. Agriculture [ ]	7. Any other, please specify [ ]…………
3. Chainsaw operations [ ]	
4. Bio fuel fetching [ ]	

10. What measure(s) do you propose be instituted to maintain the forest and revive the depleted parts? ***(You may choose more than one option)***

1. Re-forestation	[ ]
2. Controlled logging	[ ]
3. Alternative livelihood in the area to reduce dependency on the forest	[ ]
4. If any, kindly specify [ ] ………………………………………………………………………………	

11. What measures is the community putting in place to save the forest? Kindly state them?

F. KEY ADAPTATION STRATEGIES COMMUNITIES ARE ADOPTING TO REDUCE VULNERABILITY AGAINST ADVERSE IMPACT OF CLIMATE CHANGE.

1. Are you ready to meet any future challenge that may cause the decline of the forest, especially from changing weather events?

1. Yes [ ]	3. Not sure [ ]
2. No [ ]	

2. What are the key adaptation measures you are doing to reduce your vulnerability from any future changes in the weather pattern of the area?

3. Could please quantify your asset by placing financial value on it?

Alternative Livelihoods programmes as adaptation measures

4. Has there been any alternative livelihood programme(s) in this community to reduce dependency in the forest?

1. Yes [ ]	3. Not sure [ ]
2. No [ ]	

Questions 4-8 are meant for communities with running alternative livelihood programmes.

5. If yes kindly indicate,

1. Mushroom rearing [ ]	5. Bee keeping [ ]
2. Snail rearing [ ]	6. Tie and die and other vocation [ ]
3. Grass cutter and rat farming [ ]	7. Any other please indicate [ ]

4. Trading [ ]	……………………

6. Which group/organization introduced the programme?

1. State agency [ ]	6. Community Based Organisation [ ]
2. Government initiative [ ]	7. Domestic Non-Governmental Organisation [ ]
3. The District Assembly [ ]	8. International Non-Governmental Organisation [ ]
4. A philanthropist [ ]	9. Any other group kindly specify [ ] ……………..……..…………..
5. Local group/club/union [ ]	

7. Kindly specify the name of the group (s)

8. What can be done to improve the programme?

9. Why was this community chosen for such a programme?

1. Dependency on the forest is causing depletion of the forest [ ]
2. Livelihood in the forest is reducing [ ]
3. Any other reason(s), please state ……………………………………………………………………………………… ……………………………………………………………………………………… ……………………

The following questions are for communities with no alternative livelihood programme(s) running.

10. Has there been any such programme(s) here in the past?

1. Yes [ ] 2. No [ ]	3. Not sure [ ]

11. If yes, why did it stop running?

12. Which organisation introduced it?

13. How are you dealing with the continuous depletion of the forest resources?

14. Into the future, what livelihood options do you have in order to reduce your vulnerability especially against climate change impact?

15. Have the community leaders started with any initiative on their own to help community members?

1. Yes [ ] 2. No [ ]	3. Not sure [ ]

16. If yes, what is the name of the initiative?

18. Kindly state what you engage in under the said programme?

F i. KEY DETERMINANTS OF VULNERABILITY

19. Which of the following is likely to make you vulnerable in these changing times?

1. Lack of Capital	[ ]	5. Aging	[ ]
2. inaccessibility to land	[ ]	6. Increase temperature	[ ]
3. lack of alternative livelihood programs	[ ]	7. Gender	[ ]
4. rainfall levels	[ ]	8. Lack of education	[ ]

Appendix 6: Interview Guide

Focus Group Discussion Guide for community elders/leaders and community members

1. How do you understand climate change?
2. What are the signs that demonstrate a changing climate in this area?
3. Can you give a brief history of the Atiwa Forest?
4. Is the forest accessible to the community? If no, why?
5. How important is the forest to communities along the stretch of the forest?
6. What kinds of livelihoods do communities along the forest get from it?
7. What was the state of the forest ten or so years ago?
8. What is the state of the forest now?
9. Have the benefits and livelihoods you stated above changed recently?
10. How has a change in the forest now affected the benefits and livelihoods communities get from the forest?
11. Is there a relationship between the forest and the climate of the area? How?
12. Is there any alternative livelihood programmes running in this area?
13. If yes, when did it begin and which organization is running it?
14. Why was your community chosen for the programme?
15. If no, how are you coping with the current trend of decreasing forest productivity?
16. Why are there days which people don't go to the forest?
17. What is being done at the local level to help save the forest? When it started? Its nature?

For places with no formal alternative livelihood programme ongoing.

18. Has the community itself started any livelihood empowerment programme?
19. Name and source(s) of funding?
20. What are your future plans to expand the programme?
21. Does the programme have gender undertone and why?

Interview Guide: District Assembly

1. What benefits does the assembly get from the forest (be it direct or indirect benefits)?
2. What is the district doing to protect the forest and its resources from over-exploitation?
3. Are you in collaboration with the other districts assemblies that to which **ARFR** belongs to save the forest?
4. How is the district mainstreaming climate change in dealing with the forest and livelihoods in the area?
5. What alternative livelihood programme(s) is the state putting in place to deal with the people whose livelihoods will be affected by strict conservation of the forest?
6. What is the long term plan of the Assembly to protect the forest form total degradation?
7. What plan does the Assembly have for the forest?

District Forestry commission

1. How important is the Atiwa Range Forest Reserve, both locally and globally?
2. What has been the rate of protection/destruction of the reserve lately?

3. Have you heard about climate change?
4. How are you making use of this vast forest resource to mitigate and building communities adaptive capacity to climate change?
5. What are the principal causes of degradation to the forest as your outfit has identified?
6. And what are being done to salvage the situation?
7. What agencies are you collaborating to help save the forest? What have been the outcomes of such collaboration?
8. What is state policy towards the protection of the forest from destruction?
9. What is the short term plan on the forest?
10. What is the medium to long term plan of your agency to the Forest?