Assessing Climate Change Impacts and Indigenous Adaptation Strategies on Forest Resource Use in Nigeria

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Dedication

To my family for all their support

Abstract

The impacts of current global climate change vary, depending on the sector and the level of system's resilience. This study analysed the impact and adaptation mechanisms to climate change among forest communities in Nigeria using a survey of 400 households from five ecological regions of Nigeria. Data were analysed using Ricardian, logit and cost benefit analysis models. Results show that the level of forest dependence varies from 14% in the Sudan savannah to over 47% in the mangrove. Over 88% of respondents have perceived climate change impact, with 84% of respondents noticing changes in forest resource use; these changes were less prevalent in the montane forest where over 65% have noticed no changes.

The Ricardian analysis showed that the age and level of education of the household heads significantly and positively impacted on net revenue that the household derived from the forest. Predicted average annual household income from the forest was $3380. Increasing rainfall during winter and spring seasons significantly increase household net revenue by $62 and $75 respectively, and reduces income by $42 and $18 in summer and autumn respectively. A 1^{o}C increase in temperature will lead to a very negligible annual loss in household net income from the forest in all zones. The adaptation options used by the forest communities are agroforestry, erosion control, changing dates of operations, use of improved cook stove, cultural practices, irrigation and migration. The ability to notice climate change and take up adaptation strategies were positively associated with spring rainfall and winter rainfall respectively, while both were negatively associated with summer and autumn rainfall. The determinants of adaptation strategies were level of education, transportation mode, market access, detecting of climate change, household size, access to electricity, number of years of forest use, extension visits and net revenue from the forest. Primary occupation (farming) and age of the household head were negatively associated with the adoption of different adaptation options. The cost benefit analysis showed that while the use of improved cookstove had the highest net profit, turnover ratio and net present value, the use of fertilizer was the least cost effective and together with poor infrastructure were the major barriers to adaptation. Anthropogenic disturbances were shown to exacerbate land use change and forest resource loss in conjunction with climate change.

The results indicate a high level of awareness among the communities around the concepts of climate change and the perceived impacts on their forest use. Furthermore, it shows the effects of the combined interactions of climate change and anthropogenic disturbances on forest resource use which blurs the precision in the abstraction and attribution of impacts in Nigeria. This underscores the need for a further integrated research, combining the social and economic elements with biophysical perspectives of climate change impacts that can be useful for incorporating adaptation strategies into national development planning of not only Nigeria but many developing economies in order to build resilience among forest dependent communities.

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Declaration

The questionnaire and statistical coding used in this research were developed by School of Forestry and Environmental Studies (FES), Yale University (USA) and CEEPA, University of Pretoria (South Africa) with modification from the researcher. With the exception of the above and attributed parts in the texts, I confirm that this thesis is my own work and has not been submitted for any other assessment**.**

This thesis is made up of chapters containing different published and submitted papers as follows: the paper titled ‘Nigeria’s response to the impacts of climate change: developing resilient and ethical adaptation options’ has been published in the Journal of Agriculture and Environmental Ethics in 2011. The paper ‘Resource use conflict in West Africa: developing a framework for resilience building among farmers and pastoralists’ has been published in African Journal of Agricultural Research. The paper titled ‘Climate change impacts and adaptation pathways for forest dependent livelihood systems in Nigeria’ has been published in African Journal of Agricultural Research in 2014. The paper titled ‘Assessing the economic impact of climate change on forest resource use in Nigeria: a Ricardian approach’ is currently under review in the Journal of Agriculture and Forest Meteorology. The paper titled ‘Climate change perception, awareness and adaptation decision among forest communities in Nigeria’ is currently under review by the journal of Mitigation and Adaptation Strategies for Global Change. While the paper titled; ‘Determinants of adaptation strategies to climate change in Nigerian forest communities' is also under review in the journal of Regional Environmental Change. These papers have been co-authored by Rob Marchant and some by Murray Rudd. This is due to their roles as supervisor / editor and editor respectively, beside this, the thesis is solely my work and not those of the co-authors.

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NwaJesus Anthony Onyekuru

CHAPTER ONE

1.1.0 Introduction to the study

One of the greatest challenges to human kind in the 21st century is the increasing threat from climate change (IPCC, 2014). According to UNDP (2010), climate change poses great challenges to society, particularly in developing countries; impacts will reverse decade's worth of human development gains especially those of the Millennium Development Goals (MDGs) and threaten achievement of the nascent Sustainable Development Goals (SDGs).

IPCC (2014) defines climate change as a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean **of climate variables** and/or the variability of its properties, that persists for an extended period; typically decades or longer. Although the length of time it takes the changes to manifest matters, the level of deviation from the normal and its impacts on the ecology are most paramount. The earth's climate is a finely balanced system; a small rise in atmospheric temperature could produce changes to the climate worldwide, as a result, the enhanced greenhouse effect is often referred to as "climate change" or "global warming". It is 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 (United Nations Framework Convention on Climate Change (UNFCCC), 1992). Secular variations in climate occurring over a period of 100 to 150 years may not qualify as climate change if conditions will quickly reverse later (Ayoade, 2003). Thus, climate change is different from climatic fluctuations or climatic variability that denote inherent dynamic nature of climate on various temporal scales, which could be monthly, seasonal, annual, decadal, periodic, quasi-periodic or non-periodic (Ayoade, 2003).

Developing world countries, especially those in Africa, are projected to bear the major brunt of a problem caused by global environmental change. According to IPCC (2014), Africa warmed by approximately 0.7°C during the 20th century with decreased rainfall over large portions of the Sahel. UNFCCC (2007) asserts that there will be decrease in annual rainfall in much of Mediterranean Africa and the northern Sahara, increase in frequency and intensity of extreme events and increasing water stress for many countries. This is made worse by high level of poverty, low levels of infrastructure and human development, which limit the capacity of Africa to manage risks due to climate change (UNFCCC, 2007), According to Muller (2009), climate will change strongly in sub-Saharan Africa, with annual average temperature increases between 1.8 and 4.8°C and annual changes in regional precipitation ranging between –12 and +25 % (seasonal changes range from –43 to +38 %) by 2100 (2009 baseline).

According to Kurukulasuriya and Rosenthal (2003), the concern with climate change is heightened given the linkage between agriculture, the forest and poverty. In particular, it is anticipated that adverse impacts on forest resources will exacerbate the incidence of rural poverty. DFID (2009) noted that climate change impacts will be worse for the vulnerable population such as the poor, old, women and children and for those that depend on agriculture for their livelihoods, because the vulnerable are less able to fend for themselves and are less able to adapt to changing circumstances. In terms of the spatial distribution of impacts, those in the far north and adjacent to the coastline are far more at risk.

Impacts on poverty are likely to be especially severe in developing countries like Nigeria where the forest is an important source of livelihood for a majority of the rural population. A major problem for agriculture production in Nigeria due to climate change is the reduction of arable lands (DFID, 2009); while the sea incursion is reducing the arable land of the coastal plains, desert encroachment to the north of the north of the country with its associated sand dunes is depriving farmers of their agricultural farmlands and grazing rangelands. Moreover, the frequent droughts and less rain have started to shorten the growing season thereby causing crops failure and food shortage. It has been shown that drought, desert encroachment and coastal inundation have started affecting the country's ecosystem leading to ecological destabilization due to climate change impact in the semi-arid region of Northern Nigeria and the consequent ramified socioeconomic effect, which threaten social stability in the country (Odjugo and Ikhuoria, 2003; Ayuba *et al.*, 2007).

All the main sectors of the country's economy will be impacted by climate change, but in particular agriculture (BNRCC, 2008). Based on IPCC climate change assessment, DFID (2009) asserts that between 2-11% of GDP could potentially be lost by 2020, if no adaptation is implemented and by 2050 climate change could result in a loss in GDP of between 6% and 30% in Nigeria, worth an estimated US$ 100 to 460 billion dollars. The above impacts are based on possible sea level rise from 1990 levels to 0.3m by 2020 and 1m by 2050, and a rise in temperature of up to 3.2°C by 2050 under a high climate change scenario. Infrastructure such as water, transport and power are also extremely susceptible and will result in knock-on effects to other parts of the economy. All regions will be impacted, particularly the southern coastal regions and the far north of Nigeria. It is predicted that there will be economic losses of 8-30% for the North, 5-25% for the south east and south and 7-34% for the south west and Lagos due to climate change (DFID, 2009). In particular, forest ecosystems that are already under significant human pressure would be adversely affected (Oladipo, 2010), due to the ramified effects of anthropogenic interactions with climate change, thereby exacerbating the impact on the human and natural systems. These impacts have a plethora of effects on the natural resource base, upon which most of Nigerians depend for their livelihoods, resulting in socioeconomic crisis (conflicts, starvation, and unemployment) and environmental degradation. Given the current level of development, with the projected climate change and sea level rise of 0.5m to 1.0m, the capital value at risk would be between about US$8.05 billion and US$17.5 billion respectively (Federal Government of Nigeria (FGN), 2008). With 30-year development and population growth of 5% and without any measure, the capital value at risk would be between US$20.13 billion and US$43.13 billion dollars (FMoE, 2003).

Variability in rainfall and temperature exposes several physical and socio-economic sectors in the country to the impacts of climate change. The consequence of which is the erosion of the sources of the social and economic resilience of especially the rural poor as they have no other means of survival. For instance, climate change will lead to a shift in the boundaries of major ecological zones, alter animal and plant composition, aggravate soil erosion and flooding in areas of higher rainfall, erode soil fertility, heighten drought and desertification in the marginal arid zones of the country and salt water intrusion along the coastal belt. Changes in climatic variability may be as important or even have larger effects for both trees and forest organisms as changes in the average climate. For many species, it is expected that performance and survivorship will not be affected by slight, progressive changes in climatic conditions, but by the likelihood or nature of catastrophic events (Rouault *et al.*, 2006).The degradation of the forest ecosystem has obvious ecological effects on the immediate environment, but it may also affect distant areas, for instance, agricultural plains or valleys that depend upon forest highlands for their water may suffer flooding or drought as a result of the destruction of the forests (Adeofun, 1991). Genetic damages and losses of plants, animals and insects can also be serious and possibly permanent. Furthermore Giest and Lambin (2002) reported that deforestation affects the hydrological cycle through changes in evapo-transpiration and run-off. The understanding of vulnerability to climate change and the strategies and pathways for adaptation are currently enveloped in high uncertainties, particularly in developing countries where adequate scientific data is lacking in many respects (BNRCC, 2008). It will alter all aspects of the hydrological cycle ranging from evaporation through precipitation, run off and discharge (Mcguire *et al.*, 2002). The global warming and decreasing rainfall together with the erratic pattern of rainfall produce a minimal recharge of groundwater resources, wells, lakes and rivers in most parts of the world especially in Africa thereby creating water crisis.

According to European Commission Forest Institute (EFI) (2008), climate change will have impact on temporal and spatial dynamics of (potential) pest species, influencing the frequency and consequences of outbreaks as well as their spatial patterns, size and geographical range. Not only the range of the pest species may be affected, but also (in the long run) the distribution of its host tree species. An important fact is that individual species will respond to climate change not necessarily in the same way and changes of species composition of communities are to be expected in future and hosts will consequently come in contact with novel pathogens and herbivores (EFI, 2008). Thus, the coevolved relationships between hosts and their pests probably will be disturbed. In areas, where pathogens have been contained at low levels because of unfavourable historic climate conditions, changes in climate may put the associated tree species at great risk (Roy *et al.*, 2004; Woods *et al.*, 2005).

In terms of opportunities, the outcomes of climate change impacts and the response of people and the ecosystem is not all negative for Nigeria and the rest of the developing economies. This is because there exist good opportunities for the continent with respect to positive shifts that will benefit certain crops and species across Africa. For example, the warming is already favouring productivity of drought tolerant crops like sorghum and millet. In addition, there exist a plethora of opportunities regarding mitigation and adaptation, with respect to funding for climate change worldwide, though with complex architecture; red tape bureaucracy, top down approach, stringent procedures and conditions that make access to them very difficult (UNCCD and The Global Mechanism, 2013). Thus, the results of this study are vital in highlighting possible critical areas of interventions by some of these funding opportunities in Nigeria. They can be tapped into in helping to develop and strengthen targeted climate change mitigation and adaptation in the future using evidence from research such as generated in this thesis. Research is vital to support a better understanding of the extent of past, current and future climate variability and potential climate change in Nigeria, as a basis for developing adaptation options likely to ensure that poor and disadvantaged groups benefit from the adaptation process rather than bearing the burdens. In addition investment into biophysical forecasting to increase the predictability of climatic events is important for stakeholders in different sectors to manage risks due to climate change.

1.1.1 Statement of problem

In spite of the importance of forests especially in ameliorating rural poverty and a dependable source of income and food supply in rural areas, Osemeobo and Ujor (1999) observe that Non Timber Forest Products (NTFPs) are a diminishing resource in Nigeria. The continued loss of forest land and the consequent degradation of the environment have become a source of concern, especially when sustainable human needs are considered. Nigeria was once covered by extensive vegetation varying from humid tropical forest in the south to savannah grassland in the north. This extensive vegetation has over the years been transformed and high value forest reduced to a fraction of the former extent (World Resources Institute, 1992; FAO, 1997; 2005; Butler 2005). As a consequence the benefits; food, raw materials, income, employment and ecosystem services, which forest bestowed on the people are being impacted and expensive to acquire. Butler (2005) reports that Nigeria and Sudan were the two largest losers (11.1%) of natural forest from 2000 to 2005, and that between 1990 and 2000, Nigeria lost an average of 409,700 hectares of forest per year. This amounts to an average annual deforestation rate of 2.4%, while FAO (2005) put it at 3.1% between 2000 and 2005. IITA (2010) studies show that forests now occupy about 923,767 km^2 or about 10 million ha. This is about 10% of Nigeria's forest land area and well below FAO's recommended national minimum of 25%. Estimates for total tropical Africa put the total loss in the forest cover between 1990 and 1995 to be about 18 million hectares and 7% annual loss (FAO, 1997).

Forest cover degradation has a negative impact on water resources resulting from the extensive loss of watersheds due to reduced interception of rainfall, leading to an increase in the rate and volume of run-off, increased stream flow and flooding with disastrous consequences to life and property (Adeofun, 1991). In southern part of Nigeria, Adeofun (1991) asserts that coastal and gulley erosion is of greater importance. This is because these parts of the country have a long duration and high intensity of rainfall and hence erosion by water is more prominent. The consequence of this is the constant flooding and loss of arable land, crops, lives and properties in different parts of the country and the consequent refugee crises due to internally displaced persons across the country, exerting a lot of pressure on the social system and the ability of government to cope with such disasters (Oduwole and Fadeyi, 2013). Impacts on water availability, both in terms of quantity and quality, are likely to have the biggest impact on people. A simple mean across the ensemble of scenarios taken for the West African region shows slightly more rainfall in the Sahelian region and little changes along the Guinean coast, the northeast region of Nigeria will become increasingly arid with reduced surface water, flora and fauna resources (Obioha, 2008; IPCC, 2007). A uniform decrease in rainfall will hit the river flows disproportionately hard in the Sahel (Collier *et al*. 2008) where the rainy season in the north has dropped to 120 days from an average of 150 days when compared with the frequency 30 years ago (Federal Government Nigeria, 2013). A further decrease in stream flow and the inability of groundwater to 'recharge' results in insufficient water resources to maintain their current level of per capita food production from irrigated agriculture - even at high levels of irrigation efficiency (UNECA, 2008). Already rivers in West Africa discharge more than 40% less than they discharged in the 1970s (FAO, 1997).

In the northern part of Nigeria, however, erosion by wind is of greater significance. Wind erosion in this region accelerates desert conditions typical of moisture less environment, desiccating winds, drifting sand dunes and the extreme difficulty in establishing a thriving animal or plant life. These conditions constitute a precursor to desertification and its aftermath (Adeofun, 1991). The desert belt has moved from the far north to the middle belt region of Nigeria, while the Savannah interface between desert and forest is observed to be now along the Guinea Savannah belt of Nigeria. Desertification, especially around the Sahara, has been pointed out as one the potent symbols of the global environment crisis in Africa (IPCC, 2007) as the areas increasingly become susceptible to drought, land degradation and desertification. Nigeria is reported to be losing 1,355 square miles of rangeland and cropland to desertification each year, affecting 11 northern states of Nigeria (Brown, 2006). This has come with enormous economic loses and had a negative impact on the people. Land degradation and desertification constitutes major causes of forced human migration and environmental refugees, deadly conflicts over the use of dwindling natural resources, food insecurity and starvation, destruction of critical habitats and loss of biological diversity, socio-economic instability and poverty and climatic variability through reduced carbon sequestration potential (UNECA, 2008). Fasona and Omojola (2005) show that land resource use conflicts accounted for about 51% of all causes of conflicts in Nigeria between 1991 and 2005. Women and children particularly bear the greatest burden when land resources are degraded and when drought sets in. Akonga (2001) shows that most of the destitutes that migrated as a result of drought and desertification usually move to nearby urban areas to beg for alms, thereby compounding already tense urbanization and socioeconomic problems in the areas.

Most rural communities in Nigeria live in abject poverty due to the reduced flow of food, cloth, energy and shelter materials from the forest and the indirect flow of the ecosystem services derived from the forest, especially as it relate to soil fertility in crop production and support for their livestock (UNECA, 2008) and the situation is not different today. The impact of drought and climatic variability in both economic and mortality terms is generally larger for relatively simple and predominantly agricultural economies like Nigeria, drought and floods account for 80% of loss of life and 70% of economic losses linked to natural hazards in Sub-Saharan Africa (WB and ISDR, 2007).

Another very important consequence of loss of forest cover according to Roper and Robert (2006) is the degradation of the genetic pool, the permanent loss of valuable plant and animal genetic resources. Also the destruction of wildlife habitat has drastically reduced animal populations and productivity such that many rare species are now threatened with extinction; negative trend which is already impacting on the national fauna and flora resources, as most of the plant and animal species are gradually eroded, thereby affecting the biological and tourism potentials of the country (Usman and Adefalu, 2010).

Although Nigeria has made some efforts to mitigate and adapt to climate change risks, for example, Nigeria in November 2003, submitted its First National Communication to the Conference of the Parties, while the second is at the verge of completion. Nigeria has prepared the National Adaptation Strategy and Plan of Action on Climate Change (NASPA-CCN) in 2011 (Building Nigeria's Response to Climate Change (BNRCC) Project, 2011). The NASPA-CCN seeks to minimize risks, improve local and national adaptive capacity and resilience, leverage new opportunities, and facilitate collaboration with the global community, all with a view to reducing Nigeria's vulnerability to the negative impacts of climate change. Though not much has been achieved in this regard, aside from the commencement of the implementation of the Great Green Wall Sahara, it has brought the issue of climate change adaption to the front burner of National discourse among stakeholders and provides the required framework for adaptation and engagement. There is also a move by the Senate Committee on Environment to create a National Climate Change Commission. These efforts are still rudimentary especially when compared with the magnitude of present climate changes impact and the even worse predictions for Nigeria. Presently not much has been done to provide empirical understanding and answers to the impacts and there is limited knowledge on the land use measures to manage the problems, thus environmental degradation, hunger and poverty are on the increase.

From the foregoing, it has become imperative that more research is carried out in this area, in order to provide evidence that will influence not only policy, but the activities and well-being of the people. A better understanding of the interactions between climate change and forest resource use, individual and community coping mechanisms and their policy implications, in order to guide stakeholders toward resilience building among the forest communities. Especially, the social perspectives as is the case in this study is vital in complementing other scientific findings in the quest for climate change abatement and adaptation. Several studies have been carried out in the area of impact and adaptation to climate change (Deressa, 2007; Eid, *et al.* 2006; Kurukulasuriya and Mendelsonn, 2008; Seo and Mendelsohn, 2008; Deressa *et al*. 2008). All have been focused on crop agriculture in different countries and regions; none has been done in the area of impact on forest resources or in Nigeria. This research gap on assessment of Nigeria's vulnerability to climate change has also been identified by DFID (2009) which showed extensive data gaps in Nigeria, particularly with respect to assessing impacts and adaptation strategies. Key data gaps include: climatic data and trends, baseline natural resource and socio-economic conditions, location and importance of assets, data on extreme events such as drought, flooding and coastal flooding, and socioeconomic data at a local and regional level. Judging by the fact that the livelihoods of majority of citizens of Nigeria are predominately dependent on forest resources and the importance of forest resources to food security it has therefore become pertinent that such studies as this be undertaken to provide empirical evidence to stakeholders for collective action against climate change in Nigeria.

1.2. Description of the Study Area

The study was carried out in Nigeria that has an area of 923,768 km^2 and a population of 140 million (NPC, 2006). Nigeria lies between latitudes 5^o South and 13^o North and longitudes 6^o West and 8^o East. According to Ojanuga (2006) there are 19 agro-ecological zones (AEZ) in Nigeria, extending over a total land area of about 98.3 million hectares 57% of which is under crop or pasture. The remaining 43% is made up of forest (16%), rivers/lakes/reservoirs (13%) and other features (14%) (Atampugre *et al.*, 2008). Each of these nineteen agro ecological-zones, although with some unique attributes, fall into one of a broader agro ecological classification due to their similarities in rainfall, temperature and vegetation, thus they are further grouped into 5 major zones: the Sahel savanna, Sudan savannah, Guinea savannah, Rain forest and the mangrove swamp (FAO, 1999) (Fig. 1) that formed the unit of study for this thesis.

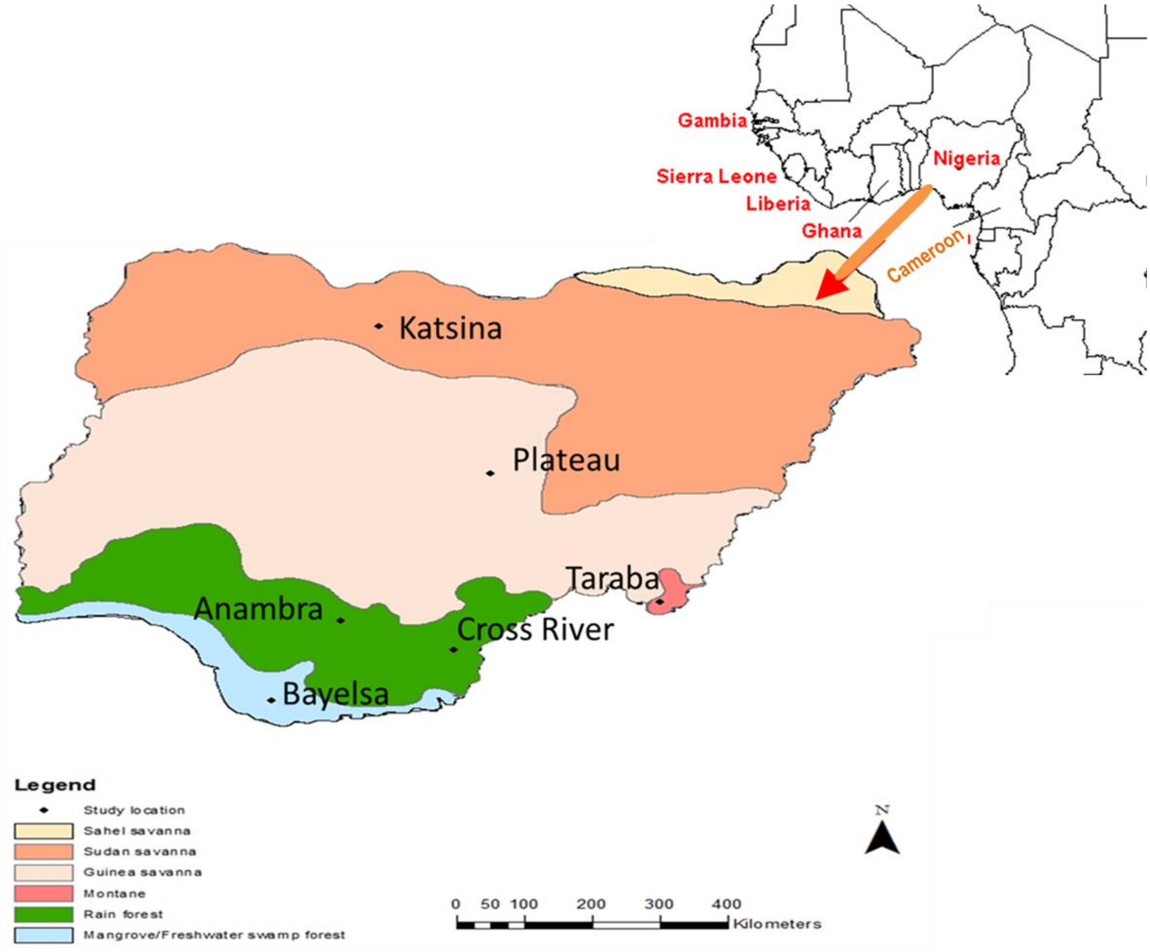

Figure 1. Agro-ecological map of Nigeria showing places used in this study

1.2.1 Forest and forest communities in Nigeria

According to Dunster and Dunster (1996), forest is defined as a vegetation community dominated by trees and other woody shrubs, growing close enough together that the tree tops touch or overlap, creating various degrees of shade on the forest floor. The etymological derivation of the term forest is thought to be quite literally, a place designated by the king for the rest of wild animals (from the Latin fera and station, meaning a safe abode or sanctuary for animals) (Dunster and Dunster, 1996) that was later compounded to foresta. The meaning of forests changed as the emphasis shifted away from retention of wildlife for hunting to more utilitarian wood and non-wood value. To the national forest inventory forest is defined as "an area, incorporating living and non-living components, that is dominated by trees having usually a single stem and a mature or potentially mature stand height exceeding two meters and with existing or potential crown cover of over storey strata about equal to or greater than 20%" (Dunster and Dunster, 1996). According to FAO (1998) a forest is an area more than 0.5 hectares with a tree canopy cover of more than 10%, which is not primary agricultural or other specific non-forest land-use. The fact that forest has been defined in many ways is a reflection of the diversity of forest and forest activities in the world and of the diversity of human approaches to forest, depending on the use derived from the forest by different people which informs their different perspectives of the forest. Forests in the context of this thesis include all resources that can produce forest products, namely, woodland scrubland, bush fallow and trees on farms, as well as ecosystems dominated by trees (Arnold, 1998). Forest communities, as defined by the researchers and used in this study; refer to those settlements living in or adjacent to forests that derive some or most of their livelihoods from the forest resources.

1.2.2 Distribution of forest types in Nigeria

The location of the different vegetation types in Nigeria are spread across different states (Fig 1), their location and characteristics has been described by Fuwape *et al.* (2006) as follows. Mangrove forest covers the land area around coast, extending 5 to 10 kilometers from the inland coastal part of Rivers State through, Ondo, Ogun and Lagos States. The fresh water swamp covers a band of 22 to 25 kilometers of land between the mangrove and lowland rainforest belt particularly in the Niger Delta. The lowland rainforest is predominant in the southern part of the country covering parts of Cross River, Rivers, Balyesa, Delta, Edo, Ondo, Ekiti, Ogun Osun, Oyo and the boundary between Cross River and Benue States. The vegetation type is characterized by tall trees with dense canopy and little undergrowth, characterized by three strata: the top layer of emergent trees that are about 45m tall; dominant layer of trees that are 20-35m tall and tertiary layer with shorter shade tolerant trees and patchy ground vegetation with a few tree saplings and herbs. The lowland rainforest also features big woody climbers and epiphytes, which are supported by the tall emergent trees.

The savanna zone occupies the upper part of the lowland rainforest in this eco-zone transition between lowland rainforest to Guinea Savanna. It spreads from the central part of Oyo State through southern region of Kwara, the northern portions of Osun, Ondo and Edo States to Kogi, Anambra, Enugu, Abia and Benue States. There are scattered tall trees, dominant layer of deciduous trees in regions adjacent to the rainforest with shrubs and dense undergrowth in places close to the Guinea Savanna. The Guinea Savanna is immediately north of the derived savanna. It is quite extensive and occupies the ‘middle belt’ of Nigeria covering substantial part of Kwara, Niger, Kogi, Kaduna, Plateau, Benue and Taraba States. The ecosystem is characterized by few trees, a lot of woody shrubs, dense undergrowth and grasses. The Sudan savanna extends across the northern part of the country from Kebbi and Sokoto States through Kano, Katsina, Kaduna, Pleatue, Bauchi, Yobe, Adamawa and Borno States. There are many shrubs and tall grasses in the savanna. The Sahel savanna is found in the arid land north of latitude 17^oN in the northern part of Sokoto, Katsina, Jigawa, Yobe and Borno States. Feathery grasses interspersed with thorny trees characterize the vegetation type.

There are mountainous districts in Nigeria that are semi-temperate in weather, they include the cold and scenic Jos Plateau, Mambila Plateau , Obudu Plateau and Biu Plateau (Wikipedia, 2010) (Fig. 1). These plateaus are montanes, over 1000 meters high; Jos Plateau is 1200 meters above sea level with temperatures ranging from 18 °C to 25°C. Mambilla Plateau located in Taraba State is the highest plateau in Nigeria with a height averaging 1800 meters above sea level. The temperature on this plateau is temperate throughout the year (it rarely goes above 25 °C during the day time making it the coldest plateau in Nigeria). The Obudu Plateau (Cattle Ranch) 1500 meters above sea level is another well-known hotspot for tourists. It has similar climatic conditions to temperate land autumn season. The Biu Plateau 800 meters above sea level in southern Borno state experiences similar cold weather conditions to Jos town on the Jos Plateau (Wikipedia, 2010)

1.2.3 Nigeria climate, climatic variation and projections

The size and characteristic relief in Nigeria give rise to a variety of ecosystems that ranges from mangrove and rainforest along the coasts to the desert in the northern parts. Coupled with variability in rainfall and temperature there are a range of different climatic niches across the country. Altitude in Nigeria varies from 0 to 1850m from the sea coast to the montane plateaus, thus giving rise to the different temperatures which ranges from as low as 10^{o}C (in the montane) to as high as 40^{o}C in the Sahel, while average mean minimum temperatures are about 8^{o}C. Mean monthly maximum temperatures are lowest in August at about 28^{o}C and highest in March at around 34^{o}C (beginning of spring). In the Middle Belt (the Guinea zones), mean monthly maximum temperatures are also lowest in August and highest in March or April, varying between 30^{o}C in August and 38^{o}C in March / April. In the far North (Sudan and Sahel zones), maximum temperatures are recorded in May (end of spring), and could be as high as 40^{o}C or more with the lowest temperatures of around 28^{o}C are experienced in December / January. According to Adejuwon (2006) mean annual rainfall along the coast and within the forest zone, could be as high as 3000 mmyr^{-1}, but usually not less than 1250 mm yr^{-1}. Although rainfall could be expected during each month, there is usually a relatively dry period of two to four months with significantly low rainfall.

1.2.4 Different seasons and their periods in Nigeria

The year in Nigeria is sharply divided into rainy season and dry season. Though the periods overlap, for ease of analysis and in harmony with other related studies in different countries the seasons are divided into winter, spring, summer and autumn in this study (Table 1).

Table 1. Different seasons and their periods in Nigeria as used in this study

Season	Season in Nigeria	Period
Winter	Peak dry season	December to February
Spring	Early rainy season	March to May
Summer	Peak rainy season	June to August
Autumn	Early dry season	September to November

The dry season is about seven to nine months long in the northernmost areas, starting as early as September to May, while it is only three to five months long in the south, starting as late as November to March. For about two of the dry season months, the area is overlaid by a dry air mass, which comes in from the Sahara Desert (the Harmatan). There is little difference between the northern, drier boundary and the southern wet boundary in terms of total annual rainfall. The boundary between the Middle Belt and the Sudan zone corresponds to a sharp drop in mean annual rainfall from 1000 mm yr^{-1} to about 750 mm yr^{-1}. In the Sahel, the rainy season is barely three months long, while in the Sudan, the rainy season extends over a period of four months (Adejuwon, 2006). For a greater part of the 20th century, there was a general trend towards aridity in Nigeria and the rest of West Africa (Adejuwon *et al.*, 1990; Nicholson, 2001). The analysis of rainfall trend in Nigeria from 1922 to 1985 by Adejuwon *et al.* (1990) and from 1970 to 2002 by Ishaku and Majid (2010) show that the trend towards aridity was more pronounced in the Sudan and Guinean ecological zones than in the forest zones and Sahel zones.

1.2.5 Projections of Climate Change in Nigeria

Despite the prevailing history and strong evidence of increase climate change impacts, there is much uncertainty surrounding climate change (Collier *et al*., 2008). Due to differential character of the climatic regions of Nigeria, increased temperature will have different effects in different locations. These effects can be either positive or negative depending on the area and the main limiting factor (rainfall or temperature) in this area. Changes in the rainfall patterns are likely to have large corresponding effects on forest productivity, particularly in regions where productivity is water limited (Kirschbaum, 2004). Rising temperatures without increase in precipitation, or with decreasing rainfall, can lead to drought (Rennenberg *et al.*, 2006). Climate variability is particularly important in connection with the changes in precipitation, because extreme events such as extended droughts and hot spells have much more drastic consequences on tree growth and survival than gradual changes in average climate conditions (Fuhrer *et al.*, 2006). Granier *et al.* (2007) document the reduced CO_2-uptake and biomass production under drought as stomata of plants are less open thereby limiting gaseous exchange between plants and the atmosphere.

A study conducted by Leary *et al*. (2007) in Sub Saharan Africa, using Nigeria as a case study, has made a significant contribution towards the understanding of the nature of present climate and the projections into the 21st century in the face of global climate change. The study comprehensively evaluated climate change situation in all ecological zones of Nigeria and identified marked variation between the present climatic conditions and what the future situation will be in the face of unfolding global warming; some of their findings are as presented below.

1.2.5.1 Mean monthly precipitation and temperature

(i) The Rainforest zone

In the rainforest zone of Nigeria there is rainfall during each month. However, there is a relatively dry part of the year from December to February when monthly rainfall is low. Though projections show that this pattern will not change during the coming century, there will be an increase in rainfall during the rainy season months and a decrease during the dry season months, a pattern that is already being noticed in the Nigerian rainforest zone. Thus, there is the probability of the dry season becoming drier while the rainy season becomes wetter; while the rainfall of each of the dry season months of December, January, and February is projected to decline respectively by 18 mm, 15 mm and 10 mm per month, the respective rainfall of June, July and October will increase by 65 mm, 20mm and 47 mm (Leary *et al*., 2007).

Mean minimum temperature is lowest in January with about 21^{o}C and highest in March or April (spring) at about 23^{o}C. However, there are indications in the projections, as it is going to happen worldwide, that as the century progresses, the night will become significantly warmer. For example, in Port Harcourt January minimum temperature is projected to rise from 21.4^{o}C to 24.6^{o}C towards the end of the century within the same vein April minimum temperature is projected to rise from 23.1^{o}C to 26.7^{o}C (Leary *et al.,* 2007). In the rainforest zone of Nigeria, the highest maximum temperatures are recorded during winter and spring, while the lowest maximum temperatures are recorded during the summer months of June, July and August (Leary *et al*., 2007). Thick clouds and heavy rainfall downpours depress maximum temperature levels at the height of summer. Projections from 2006 show that this pattern of seasonal distribution of maximum temperature will be maintained during the 21st century. The highest temperatures will continue to be recorded in February while the lowest maximum temperatures will continue to be recorded in August. However, projections indicate that as the century progresses, the forest zone in Nigeria will become warmer as day time temperatures rise by about 3 to 4^{o}C (Leary *et al*., 2007).

(ii) Guinea zone

The nights in the Southern Guinea zone are usually cool with temperatures in the range of 18^{o}C to 25^{o}C. Projections for the 21st Century indicate a general increase in minimum temperature for all the months. They vary from as high as over 5^{o}C for January to less than 3.5^{o}C for August. With these increases, the nights are still expected to remain cool with temperatures in the range of 20^{o}C to 28^{o}C, while in the Northern Guinea zones, there will be a steady and consistent increases in mean minimum temperatures to over 30^oC (Leary *et al*., 2007). Mean monthly maximum temperatures are over 30^oC from October to May and less than 30^oC from June to September, projections from 2006 show that day temperatures will increase as the climate change unfolds. The magnitude of the increase will be of the order of 4^oC to 5^oC. Towards the end of the century, mean day time temperature will be higher than the normal human body temperature.

In the southern Guinea Savannah zone, rain could be expected during any month of the year. However, in most years, November through to March are dry and is projected to continue into the 21st century with a decrease in rainfall for the first four months of the year in some parts; normally dry months will become drier through the century. In very dry years, the rainless period may start in October and terminate in April. Heavy downpours begin in May and terminate early in October; with peak rainfall in August. While the onset of the rainy season is gradual, its cessation is often quite abrupt (Leary *et al*., 2007).

(iii) The Sudan Zone

Baseline period conditions in the Sudan zone indicate an effective rainy season only four months long with six of the dry season months being rainless. Although the onset of the season is in May in most years, the fields are not sufficiently wet for planting until June (Leary *et al*., 2007). Projections of minimum temperatures into the 21st century indicate steady and consistent increases from 4^oC to 5^oC for all the months up to the end of the century. This implies that the seasonal patterns in which the lowest temperatures are experienced in January and the highest temperatures are recorded in April will be maintained (Leary *et al*., 2007). Observed mean monthly maximum temperatures for 1961 to 1990 show that day temperatures in the Sudan Zone are lowest in January and highest in April. And there were higher maximum temperature for each month of the year, in the Sahel zone. The differences in maximum temperature between the two zones average about 2^oC. In the Sahel the lowest mean monthly maximum temperature projections vary from about 3.5 to over 5^oC during the 21st century, while for April, the difference between human body temperature and the mean maximum would be as high as 8^oC (Leary *et al*., 2007).

(iv) The Sahel zone

For the Sahel zone, baseline climate indicates a rainy season three to four months long with dry season is eight months long and largely rainless. Although the onset of the season is in May, June in some years may not receive as much rain as to make planting feasible. Rainfalls in sufficient amounts only in July and August. Projections of rainfall during the 21st century indicate an increase in rainfall for June, July and August up to 2069 followed by a decrease during the final thirty years of the century. The significant increases in the rainfall of June will tend to bring that month more effectively into the planting season (Leary *et al*., 2007).

Mean minimum temperatures are higher in the Sahel than in the Sudan every month of the year. The seasonal distribution is more or less the same. The lowest minimum temperatures are expected in January, while the highest occur in May (spring). The nights will still be cool for most of the year. However, during the three months preceding the onset of the rains nights will be relatively warm and also uncomfortable because of the associated high humidity (Leary *et al*., 2007).

1.3 Forest Resources Use and Dependence in Nigeria

1.3.1 Introduction

The majority of Nigeria's poor live in the rural areas and is dependent directly or indirectly on agriculture and its related activities while owning or controlling few physical productive assets (Eboh, 1995, Ezeani, 1995). Arnold (1998) asserts that forest provides households with income, ensures food security, reduce their vulnerability to shocks and adversities and increase their wellbeing. Different parts of a plant or animal often provide different products simultaneously and or at different times. About 80% of the population of the developing world depends on NTFP for their primary health and nutritional needs (Sophanarith, *et al*., 2008).

1.3.2 Classification of forest products

According to Balogun (2000), forest products can be broadly divided into wood and non-wood forest products (NWFPs) in Nigeria, it is commonly referred to as major and minor forest products. Major (wood) forest products includes products like timber, pole, plywood, veneers and charcoal, while minor (non-wood) forest product include products such as dye, tanning, gums, canes and herbs. The wood forest products are further classified into the timber and non-timber forest products (NTFPs). Rijsort (2000) defined NTFPs as all tropical forest products plants and animals or parts thereof other than industrial timber, which are (or can be) harvested for human or for commercial purposes. According to FAO (1999) NTFPs are defined as forest materials derived from soil mineral, water, fauna and flora resources other than round wood (sawn wood). The distinction between NTFPs and NWFPs is that while the former is made up all forest products (including NWFPs) that are not timber, the later are all forest products that are not woody (FAO, 1999). Non-wood forests products consist of goods of biological origin other than wood that are derived from forests and other wooded land and trees outside forests (FAO, 1999). In this study, the focus was on the broader range of NTFPs. Furthermore Linberg *et al.* (1997) grouped forest services into ecological services, economic services, sociocultural services, scenic and landscape services and values.

Aiyeloja and Ajowole (2006) identified some of the NTFPs in Nigeria as fruits, nuts, honey, insects, animals, fodder, fibre, fertilizers, medicinal extracts, construction materials, cosmetic and cultural products, natural dyes, tannin, gums, resins, latex and other exudates, essential oils, spices, edible oils, decorative articles, horns, tusks, bones, pelts, plumes, hides and skins, non-wood lignocellulose products, phytochemicals and aroma chemicals. These products are derived from a variety of sources - plants (palms, grasses, herbs, shrubs, trees), animals (insects, birds, reptiles, large animals) and other non-living components of the ecosystem.

Furthermore, FAO (1999) classified the NTFPs into non-wood and non-timber products. The non-wood products are derived from wild animals, herbs, leaves, latex, gum, resins, ropes, fruits, seeds, fungi, fodder, forage, gravel, clay, limestone and natural salt. The woody but non-timber products include poles, fuel-wood, charcoal, rattan canes, sponge, chew sticks and bamboos. According to FAO (1999) there is no complete list of NTFPs in Nigeria, because most biotic species from which forest products are derived are not well documented. Moreover the diversity of biotic resources and their utilization among different ethnic groups make the assignment of plants to different loci along NTFPs continuum in considerable disarray. The classification of NTFPs remain somewhat problematic because some plants fit in more than one category such as food, medicine, forage, alcohol, industrial and edible oil, spices and mat weaving (FAO, 1999). The non-timber products are also sub-divided into utilization groups such as household utensils, domestic-industrial energy, agricultural tools, traditional culture and medicinal uses (Davis and Richards, 1991).

The woody but non-timber products play a central part in the socio- cultural and economic life of rural Nigerians. They are often used for household utensils, carvings agricultural tools, chew sticks and musical instruments. The main product is fuelwood. Some of the non-timber products identified by FAO (1999) are chewing sticks, household utensils and fuelwood. In terms of volume of wood content, chew sticks are the most expensive wood in Nigerian forests. Household utensils include baskets, trays, mortar and pestles, stools carving and agricultural tools, music and arts. The *Raffia* species obtained mainly from the mangrove/fresh water swamp forests can yield ropes, thatching materials (leaves and ropes), mats, wrapping leaves, poles used for construction, scaffolds, musical instruments, fastening hooks, fishing nets, cones used for holding house-blinds and ornaments for decoration and holding of ties and brooms. Virtually all species of shrubs and trees are used as fuelwood. Fuelwood is collected from cultivated and uncultivated areas in all the eco climatic zones.

1.3.2.1 Forest foods derived from floral products

Among the various communities, most of the species are cultivated in gardens and farms for ease of access, control and management. Mushrooms are mainly seasonal and harvested from the wild and are both used for food and traditional medicine (Adjanohoun *et al*., 1991). Some of the key floral products are as described below by Adjanohoun *et al*. (1991);

(i) *Gnetum africana*

This is a plant of the moist forests but occurs in the drier terrains of this forest zone. Its main product is leafy vegetable which is cherished for making various vegetable soups amongst the people of Eastern Nigeria (Adjanohoun *et al*., 1991).

(ii) *Irvingia gabonensis*

Out of 171 indigenous woody plants of economic importance identified by Okafor (1980) within the forest zone of Nigeria, *Irvingia gabonensis* ranks amongst five principal fruit. *I. gabonensis* occurs in the forest zone as bush mango and for other medicinal purposes and a major tree crop for agroforestry systems in the country.

(iii) *Gum Arabic*

According to FAO (1999) gum arabic is produced by four species of the Sudan savannah zone of northern Nigeria. Tree species that produce gum arabic are notably *Acacia senegal, Acacia seyal, Acacia raddiana* and *Acacia arabic*. The species which are drought resistant produce different grades of gum (gum arabic). The gum is extracted during the dry season and is used for medicine manufacture, for confectioneries and the textile industry. The wood of the species is hard and is used for carrying agricultural implements used by the people of the zone. The leaves also serve as fodder.

(iv) *Shea Butter*

Vitellaria paradoxa, the species that produce shea butter, grows in the Guinea and Sudan Savanna vegetation zones, the nuts are processed by women using traditional methods into oil, fat and meal (FAO, 1999). The extracted oil is used domestically for consumption. The fat is used for medicinal purpose in cosmetic industry, while the meal is used for feeding livestock. It is used in agroforestry systems by local farmers.

(v) *Balanites aegyptiaca*

FAO (1999) identified *Balanites aegyptiaca* as a common species of the Sudan savannah, often occurring in clusters. The wood is suitable for handcraft carvings for household use. The villagers use it to carve pestle, food mixer and handles of hoes and axes. The wood is also good for charcoal production. The fruits, the leaves and the seed or nut are useful products to the communities, being consumed by humans. The leaves also serve as fodder.

1.3.2.2 Forest foods derived from fauna resources

Virtually all faunal species, except those forbidden by taboos, folklores and found not suitable for consumption, are used for food (Osemeobo, 1994). The use of fauna resources for food varies among the various communities in accordance with the species occurring in their environment. The faunal products are in form of worms, insects, frogs, reptiles, molluscs, fish, mammals and birds. Wild animals used for food (bush meat) are found in all the ecozones. Most of the animals are herbivores and are hunted more for food in the rainforest areas where livestock is not so common. In the forest ecosystems, the main wild animals hunted for food are rodents, birds, snails, frogs and reptiles (FAO, 1999). Men carry out wildlife hunting, while the collection of snails, worms and insects is mostly carried out by women and children.

In mangrove and fresh water swamp forest ecosystem caterpillars of a beetle are a valued delicacy and much collected. The caterpillars thrive on dead trunks of Raffia and Oil Palms (FAO, 1999). Other faunal resources of this ecological zone include various kinds of fish and amphibians, molluscs, for example, periwinkles, are also cherished as food in addition to oysters, shrimps and crabs. Bees in this ecosystem help to produce honey and wax. Some birds are hunted for food, feathers and recreation. Reptiles are also hunted for their skins, food and recreation (FAO, 1999).

In the rainforest zone, mature grasshoppers, flying termites and crickets are delicacies, especially for children after roasting. Generally in this zone, a variety of snails and mammals are harvested. Religious cultural beliefs forbid certain communities from eating some species which are cherished by others. Some such animals that are eaten only by particular group or sections of the society in the forest zone include snails, monkeys, pythons and tortoises, while rodents, antelopes, duikers and monitor lizards appear to be universally eaten (FAO, 1999).

1.3.2.3 Medicinal products

Over 90% of Nigerians in rural areas and about 40% in the urban areas depend partly or wholly on traditional medicine (FAO, 1999). In the use of NTFPs, traditional medicine and traditional religion are inseparable as they both rely on soil minerals, flora and fauna resources (Osemeobo, 1993).

(i) ***Flora products of medicinal value***

Osemeobo (1992) is of the opinion that virtually all native species of plants are used for the treatment of one ailment or another. These involve traditional medical use for preventive, curative and magical purposes. For the traditional religion NTFPs is used for divination, masquerades, shrine worship and musical instruments. All plant forms and parts are used for traditional medicine, including leaves, flowers, fruits, seeds, nuts, and tubers, roots, seedlings, latex and forest litter. Differences exist in the drug or nutrient contents of plants according to the species, types, age of plant the part of plant utilised, the time of harvesting seasons of plant growth (Osemeobo, 1992).

(ii) ***Fauna resources of medicinal value***

A lot of faunal resources are not accepted for food and are not socially accepted because of taboos are used for traditional medicine. The wide diversity of these products can be exemplified by the African giant land snail that is used for food and traditional medicine (Table 2).

Table 2. The utilization of the African giant land snail (*Archachatina marginata*) for culture and traditional medicine (from Agbelusi and Ejidike, 1990; Osemeobo, 1992)

Parts of the body used	Uses in traditional medicine	Uses in the body used traditional culture / region
Fluid	* Cure of headache * Prepared in concoction for curing new babies' sickness * Cure of malaria * Used for blood clotting during circumcision and to stop bleeding in a cut or wound. * Treatment of dysentery * Suppression of high blood pressure. * To cure eye problems * Cure of small pox	* Sacrifice to idols of iron (Ogun) idols of oracle (Ifa) and thunder (Sango) * Sacrifice during new yam festival
Shell	* Treatment of dysentery * Treatment of stomach ache * Anti-rheumatic * used for against body pains	Storage of magical charms and for festival (Ovosun in Ondo State).
Meat	* Treatment of infertility in woman * Cure of convulsion in new babies * Treatment of bone fracture * Cure of anemic patient	* To ward off evil spirits. * To appease the gods. * Used to prepare talisman for protection

The utilization of faunal products is clearly based on small part utilization such as skins, claws, feathers, bones, faeces, scales, fur and others. Despite this however, some animals are specifically hunted for traditional medicine, particularly for protective, curative and magical powers.

1.3.2.4 Other non-wood products

Other non-wood forest products identified by FAO (1999) are fodder, wrapping leaves and mats. The plant parts such as new flush of leaves, flowers and fruits often produced in the dry season are rich in proteins, vitamins and minerals that are used to feed farm animals (NAERLS, 1992). Wrapping leaves are used to preserve *Cola nitida* and *C. accuminata*. Others are used to store food items and to sell food items like moi-moi, eko, meat and akara. Mat weaving is a major rural industry in the savannah area where mats commonly used to demarcate homesteads for privacy among family units.

1.3.3 Regulatory Ecological services

Primarily Regoniel (2014) define regulatory ecological services as exchanges of energy and nutrients in the food chain which are vital to the sustenance of plant and animal life on the planet as well as the decomposition of organic matter and production of biomass via photosynthesis. Forests ameliorate local climate, provide consumption goods, health improvement, regulate local and global climate, buffer weather events, regulate the hydrological cycle, wildlife habitat, protect watersheds and their vegetation, carbon sequestration, water flows and soils, psychological services, improve property value and aesthetic, filtration of air pollutants, improvements in local air quality, energy savings by providing shading and insulation and provide a vast store of genetic information (Simpson, 1998; Brack, 2002; Nasi, *et al.,* 2002 McPherson *et al*., 2005; Sugiyama *et al.,* 2008; Pandit and Laband, 2010a and b; Donovan *et al.* 2011; Escobedo *et al.* 2011; Pereira *et al.* 2012; Pandit *et al*., 2012; Pandit *et al.,* 2013). These regulatory ecological services are divided into ecological functions and ecological services; while the former are natural process or characteristic exchanges of energy that take place in the various animal and plant communities of the different biomes of the world, which are vital to the sustenance of plant and animal life on the planet as well as the decomposition of organic matter and production of biomass made possible by photosynthesis, the later are ecosystem functions that are directly beneficial to humans (Regoniel, 2014). In other words; functions only become services to the extent that humans value them within their social systems of value generation (Nasi *et al,* 2002). Specifically some ecosystem functions are;

- The production of shoots by young plants to produce biomass and achieve growth
- Dead organic matter decompose into humus
- Plant seeds disperse in various places through special accessory parts or animals as vectors and germinate in areas where they get deposited
- Animals find their mate and reproduce
- Waste materials are degraded and recycled back into the soil
- Grazing and predation take place balancing plant and animal population (Regoniel, 2014)

Examples of ecosystem services are:

- The photosynthetic processes removes carbon dioxide from the air and supplies oxygen
- Trees serve as sources of timber
- Animals supply the protein needs of humans, serve as pets or provide animal skin for making shoes, bags, and other derivatives
- The watershed provides fresh, clean water for human consumption
- Trees serve as buffer against storms preventing destruction of houses by strong winds
- Some species of plants can cure human ailments
- Humus from decomposition of organic matter serve as natural fertilizer in areas cleared for agriculture (Regoniel, 2014).

1.3.4 Sociocultural services

For millennia, humanity has had a social and cultural basis for protecting nature. FAO (1990) asserts that forests are home to millions of people world-wide, and many of these people are dependent on the forests for their survival and many people have strong cultural and spiritual attachments to the forests. In this regard, Nigeria, being a very cultural diverse nation has sustained its cultural diversity with resources linked to the forest. Most of the cultural artifacts, costumes, instruments are products of the forest and cultural activities are performed in different forest settings with a plethora of faunal and floral species that are cultural symbols or are cultural associations with different cultures; taboos, sacred forest, evil forests / streams and animals and shrines (FAO, 1990). Therefore, forest destruction undermines the capacities of these people to survive economically, culturally and spiritually (Sousson *et al.,* 1995).

1.3.5 Scenic and landscape services and values

Scenic and landscape services are more general set of services highlighting ideas of aesthetics and beauty as components of services of forests. From a tourist's perspective, these values may be high on their decision making priorities and protection of these services are important for ecotourism. Nigeria is very rich in such ecotourism hotspots and thus has the potential of generating huge income from this sector if adequate attention is paid towards their development.

Unlike forest products, most forest regulatory service values are not paid for, and those who own or control forests where those services are produced, do not capture the economic benefits that result from those services. This is largely due to the difficulty in capturing the flow and quantifying the services such as better fishing and hunting, cleaner water, better views, free pollinators, safer or less vulnerable areas to natural disasters, lower global warming, new discoveries for pharmaceutical uses, more productive soils (Nasi, *et al.* 2002). This gap in estimation is in part due to the lack of consensus regarding a universally accepted common metric that can be used in such measurement. However, economists and others have tried to measure various services, economic and otherwise, using the metric of economic value such as willingness to pay, hedonic pricing and travel costs estimations (Pandit and Laband, 2010a, 2010b; Donovan *et al.* 2011; Pereira *et al.* 2012; Pandit *et al.*, 2012; Pandit *et al.*, 2013). It should be stressed that non-economists often oppose the use of this metric and that the metric requires strong assumptions. Nonetheless, estimates of the economic value of various services of forests do provide one indication of their importance relative to each other and to timber production and non-timber forest products.

1.3.6 Forest dependence in Nigeria

The greatest single use of forest is the provision of wood fuel for domestic cooking and heating in rural areas and among the urban poor (Oriole, 2009). Other uses at the local level include pole-size wood for housing, fencing, and furniture, sawn timber for constrictions and joinery, weaving fibres for baskets, nets and furnishing, special woods for drugs, incense and carving. Others uses of forest include watershed protection to control runoff, storage and soil nutrient maintenance; atmospheric regulation as in the case of absorption of solar heat in evapotranspiration and sequestration of CO_2. For erosion control, forest serve as shelter belts, dune fixation rehabilitation of eroded terrain and as land bank for soil nutrient and provide structure. Forests support many industries and provide materials for export: pulpwood for newsprint, papers and boards, containers, textiles; veneer logs for plywood and furniture, sawn timber for lumber, furniture, joinery and construction, poles for pit prop, transmission poles and residues for boards (Oriole, 2009).

Non Wood Timber Products also provide raw materials for large-scale industrial processing; including processing of internationally traded commodities such as foods and beverages, confectionery, flavourings, perfumes, medicines, paints and polishes. There has been a reasonable and noticeable shift from the earlier bias in favour of orthodox medicine to greater acceptance of traditional (herbal) medicines in Nigeria as in many other countries worldwide (Akunyili, 2003). Over 90% of Nigerians in rural areas and 40% in urban areas depend partly or wholly on traditional medicine (Osemeobo and Ujor, 1999). According to FAO (2010) statistics, some 35,000 plant species have been used for medicinal purposes, an estimated 80% of the world’s population depends largely on traditional natural medicines – mostly derived from plants and over 25% of the drugs in modern pharmacopoeias are originally plant based. Many agricultural communities suffer from seasonal food shortages, which commonly occur at the time of year when stored food supplies have dwindled and new crops harvest is just beginning. Forest foods are used extensively at such periods and during emergencies such as floods, famines and droughts. Where people have had relatively unrestricted access to forests, forest food is often particularly important for poorer groups within the community. Arnold (1995) asserts that while forest gathering activities are not restricted to the poor, the latter depend on these activities to a greater extent. They are therefore most likely to be affected by a reduction in the availability of such foods as the forest resource is reduced, degraded or becomes inaccessible to them. In some areas markets for forest foods have grown rapidly - for example, that for bush meat in West Africa. Perhaps the worst impact is that poorer people's food options are being progressively reduced (Arnold, 1995).

As farm size and productivity decline under pressures of increasing populations, the capacity of farm households to maintain food self-sufficiency progressively declines and they are forced increasingly to turn to cash crops and to off-farm **sources of** employment like the forest (Liedholm and Mead 1987). These products, apart from being sources of revenue for the government, are sources of income and food for the local communities around the forests. The significance of forest products income for most farm families is more in the way it fills gaps and complements other income, than in its share of overall household income. Though the contribution of income from forest products may be supplemental, the sales of NTFPs have been found to contribute as much as a quarter of total household income (Malla, 2000). According to Liedholu and Mead (1993) research on non-farm rural employment and income as a whole has shown that small scale production and trading activities in forest products constitute one of the largest parts of rural non-farm enterprise employment. Another study by Osemeobo (2005) in three ecological zones of Nigeria identified that wild plant products supported 11 occupations in Nigeria. NTFPs provide off farm employment to a large segment of the rural population and account for an enormous share of household income, while small forest based gathering and processing enterprises provide one of the largest sources of non-agricultural employment and income to rural people (Kilby and Liedholm, 1986). For example, in 1996 in southeastern Nigeria, 35.7% of the rural population collected NTFPs daily and it accounted for 94% of total income from minor sources (Nweze and Igbokwe, 2000).

According to Inonio (2009), although, the exploitation of firewood is done primarily as a source of energy to the rural households in Nigeria, it has a great deal of effect on their economic wellbeing. The main groups of traded products which first undergo simple processing at the household or small enterprise level are furniture, other products of wood - such as baskets and mats and other products of canes, reeds, grasses - and handicrafts. The first two product groups serve predominantly rural household and agricultural markets, and are usually their principal source of supply, while much of the handicrafts output goes to urban markets (Inonio, 2009). As with forest foods, forest based income and employment opportunities are particularly important to the poor - because of ease of access and very low thresholds of capital and skill needed to enter and engage in most of them. They also enable a high level of participation by poor women, who often dominate activities such as mat and basket making which may be performed in or near the home, thus allowing them to combine these income earning activities with other household tasks. Trees are also employed as a form of savings which can be drawn down when needed, to finance capital expenditures or to tide the household over an emergency. In short, farmers widely incorporate and maintain trees as a form of insurance (Arnold, 1995).

Some of the NTFP collections, especially honey are very valuable. Secondary forests in the savanna zones are used for animal grazing. Rehabilitated secondary forests are managed by the government, essentially as National Parks and Game Reserves, Zoological Gardens, Nature Reserves for Scientific Research (Arnold, 1995). They are strictly used and individuals enter the forest with special permission. The total volume of merchantable wood in all the secondary forests in Nigeria is estimated to be around 473.6 million m^3 (Osemeobo, 2005). All secondary forests in Nigeria, but especially those in the arid north, help to ameliorate the climate, stabilize the soil, replenish soil nutrients, preserve watercourses, check erosion, and provide grazing (Osemeobo, 2005).

1.4 Adaptation to Climate Change

1.4.1 Introduction

Four response options have been identified as key to addressing the negative impacts of climate change: adaptation, mitigation, technology and finance (IFAD, 2008; Spratt and Ashford, 2011; FAO, 2012). While the last three can be subsumed into mitigation; options aimed at reducing greenhouse gas emission, the first is aimed at coping or managing climate change impact. Although mitigation and adaptation aim to avoid or limit the potential damage from climate change, they approach the problem from different perspectives; mitigation aims to address the causes of climate change, while adaptation responds to its impacts (Suziki, 2012). Of all, adaptation is most likely the most practical and pro-poor option, especially among developing countries with insignificant emission history and therefore with no immediate obligation to cut greenhouse gas emission. In addition they are already being impacted upon by climate change and therefore have the need for immediate adaptation (IPCC, 2014)

1.4.2 Climate change mitigation

Mitigation seeks to reduce the level or rate of change by controlling greenhouse gases to stabilize climate change at an acceptable limit (Nyong, 2005, IFAD, 2008). Mitigation involves reducing greenhouse gas emissions and nurturing forests to absorb carbon dioxide through carbon sequestration, forest protection, renewable energy production, conservation tillage, agroforestry and rehabilitation of degraded crop and pasture lands. These are made possible by putting in place policies and the right incentives; such as subsidies for soil conservation, taxes on unsustainable production practices and payment for environmental services, which are the functions of the different governments (IFAD, 2008). IFAD (2008) is of the opinion that some mitigation options could provide new opportunities to hundreds of millions of smallholder farmers, pastoralists and forest dwellers, through their roles as sequesters of carbon, through the changes they can make in their land use and cultivation practices to reduce GHG emissions, and as small scale producers of clean energy; for example agroforestry and energy cookstove.

IFAD (2008) has identified three major options for achieving climate change mitigation:

- *Reducing emissions* of methane, carbon dioxide and nitrous oxide through efficient management of the flows of these gases in agricultural ecosystems.
- *Enhancing removal of carbon dioxide:* carbon recovery and carbon storage through improved management of agro ecosystems e.g. agro forestry.
- *Avoiding (or displacing) emissions:* crops and residues from agricultural lands can be used as a source of fuel, either directly or after conversion to fuels such as ethanol or diesel. GHG emissions can also be avoided by agricultural management practices that forestall the cultivations of new lands now under forest, grassland or other non-agricultural vegetation.

1.4.3 Technology for adaptation

Technology has a significant role to play in tackling the causes of climate change and helping people adapt to its impact. This can be in the areas of developing new, cleaner technologies, and plant breeds that are more resilient to climate variability; Cleaner and more efficient technologies include carbon capture and storage technologies through to early warning systems for extreme weather events, technologies for adaptation (IFAD, 2008).

1.4.4 Financing adaptation

Financing involve massive shifts in investment patterns across a huge range of sectors, from power generation to agriculture and forestry (IFAD, 2008). It is therefore advocated that the carbon market, which is already playing an important role in shifting private investment flows be significantly expanded to address needs for additional investment and financial flows and multilateral financial institutions, bilateral and multilateral aid agencies and, the United Nations, all have important roles to play in this regard. Good examples of frameworks and partnership that are relevant in this regard are the Clean Development Mechanism, the Clean Energy Investment Framework and the Global Environment Facility (GEF) (IFAD, 2008). The Global Environment Facility (GEF) is the primary institutional structure through which most of the funds set up under the UNFCCC and the Kyoto Protocol are channeled. There are four financial resources for adaptation currently managed by the GEF: the Least Developed Countries Fund (LDCF), the Special Climate Change Fund (SCCF), the Strategic Priority on Adaptation (SPA) under the GEF Trust Fund and the Adaptation Fund (GEF, 2007). In addition, a number of bilateral funding agencies from countries such as Canada, Germany, the Netherlands, Japan, the United Kingdom and the United States have allocated funding for adaptation activities such as research and pilot projects. Also the World Bank, UNDP and others (such as the Asian Development Bank) have initiated facilities to meet the growing funding needs for adaptation, mitigation and technology development. UNDP's MDG Carbon Facility is a mechanism, *inter alia,* to increase access of developing countries to carbon finance and leveraging networks, expertise and management capabilities to support the development of quality projects in poor developing countries to support the achievement of the MDGs, specifically the goal of sustainable development. These and other mechanisms are important in helping stakeholders to contribute to climate change mitigation (IFAD, 2008). However, access to most of these funds by smallholder farmers so far has been rather limited; with a lot of barriers to access, the complexity of project design and implementation, and the need to comply with overwhelming, administrative and financial management requirements have been identified as most critical (Solomon, 2007).

1.4.6 Adaptation

Adaptation to climate change refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC. 2014). It includes all activities that help people and ecosystems reduce their vulnerability to the impact of climate change, and that minimize the costs of natural disasters (IFAD, 2008). According to Aguilar (2001) and IPCC (2014) adaptation can be both autonomous and planned and depend on the capacity of the adapter. Autonomous adaptation is the ongoing implementation of existing knowledge and technology without official government or institutional interventions and policies in response to the changes in climate experienced. In other word they are individual and independent precautionary or corrective reactions in the face of adverse changes in climatic conditions, e.g. migration, plant replacement, changing time of activities and planting deep. Many rural communities and indigenous peoples have been maintaining a balance between natural resource use and sustainable development for centuries, adapting autonomously to natural climate changes. On the other hand planned adaptation is the increase in adaptive capacity by mobilizing institutions and policies to establish or strengthen conditions that are favourable to effective adaptation and investment in new technologies and infrastructure (IFAD, 2008). A longer-term planned approach for adaptation has to incorporate additional information, technologies and investments, infrastructures and institutions, insurances, safety nets and cash transfers to reduce vulnerability to shocks and integrate them with the decision-making environment. Technical options of planned approach include many forms of land use and land use change, new cultivation practices, new seed varieties, appropriate incentive structure, such as targeted payment for environmental services, which can expand the options that poor communities and indigenous peoples can have for both adaptation and mitigation (IFAD, 2008).

Adaptive capacity is the ability of communities and individuals to adjust to climate change, to moderate potential changes, to take advantage of opportunities or to cope with the consequences. The adaptive capacity of individuals or social groups varies, and is dependent upon their access to and control over resources. (Building Nigeria's Response to Climate Change (BNRCC), 2011). Key risks and risk levels vary across regions and over time, given differing socioeconomic development pathways (health, wealth, education, employment, political process and participation), vulnerability and exposure to hazards, adaptive capacity, and risk perceptions (BNRCC, 2011).

1.4.6.1 Classification of adaptation

Adaptation measures are classified into three broad categories: natural resource management (NRM)-based, market-based, and institutional based (UNDP, 2009), which could be implemented individually or simultaneously depending on the conditions on the ground. Natural resource management based options focus on the sustainable management of land, water, soil, plant and animal resources and combines land conservation and productivity enhancement practices, such as improved herd management, rainwater harvesting, and home gardens, soil and water management, improved tree management, cropping pattern adjustment, drought tolerant crop and irrigation (UNDP, 2009). Market-based options are those that aim to improve market access and result in increased incomes, hereby reducing vulnerability, e.g subsidy, future market and credit. Institutional options focus on local-level structural change such as extension and education, micro-credit, migration, early warning systems and improved climate information, emergency relief, market-based risk management mechanisms such as insurance-related instruments and disasters management (UNDP, 2009),

1.5 **Objectives**

This study is aimed at assessing the impact of climate change on the use of forest resources in Nigeria and the indigenous adaptation practices that has been used by forest communities in their quest to adapt to climate change in forest management in the country using a questionnaire (appendix 1). Specifically, the following objectives will be realized:

i. Assess the perceptions about the impact of climate change on the use of forest resources in different agro-ecological zones of Nigeria.
ii. Determine the impact of climate change on the use of forest resources in Nigeria.
iii. Analyze the determinant and adoption of adaptation options against climate change in Nigeria and
iv. Determine the cost effective indigenous adaptation practices for forest management in Nigeria.

1.6 Hypotheses

This research is anchored on the following hypotheses:

HO: 1 Climate change has no significant impact on the use of forest resources in Nigeria.

HO: 2 Socio-economic, agronomic and climatic factors do not affect the use of adaptation strategies against climate change in the country.

1.7 **Methodology**

Primary data was collected for this study in 2011 with questionnaires. The questionnaire and statistical coding used in this research were developed by the School of Forestry and Environmental Studies (FES), Yale University (USA) and the Centre for Environmental Economics and Policy in Africa (CEEPA), University of Pretoria (South Africa) with modification from the researchers. The questionnaire was used because of its comprehensive nature in detailing the variables and elements useful in such climate change research, in addition it has been developed and used by the research team of the author of the Ricardian model – Mendelsohn, in Yale University and it has been adapted for most climate change studies in different countries. The questionnaire evolved through several modifications, editing and correction between the researcher and the supervisor, with inputs from the Technical Advisory Committee (TAC) members for the research in the University of York. Finally it went to the ethics committee for final approval. Elements covered in the questionnaire were issues on the personal characteristics of the household (head), their agro – forestry activities, types of forest, forest governance, access to forest, forest management, forest resource use and dependence, climate change perceptions and awareness, forms of climate change impacts and adaptation strategies adopted, cost and benefits of adaptation and constrains to adaptation.

In Nigeria, the research team was brought together considering their levels of education and experience in such social research, their knowledge of the local languages in the selected communities and their availability for the duration of the study. They were practically trained by the researcher on the different components of the questionnaire and the overall expectation of the research. In order to test the questionnaire a pilot study was conducted with few respondents to validate the actual interviews and address issues and areas of concern. After the pilot study, while some of the questions were found to be ambiguous,, the respondents were reluctant to answer some. For example questions like: ‘Monthly income of the household’ was changed to ‘monthly income of household head’; ‘distance to the market’ (in miles) was change to ‘distance to market (in Km)’. These issues were suitably addressed and the questionnaire modified.

Through a house to house visit of the randomly selected households by the research team in five different ecological regions of Nigeria (Fig. 1) over 450 interviews of the household heads were made in three months and documented in the questionnaire. Samples were selected by taking a proportion of the relative size of the population of the forest communities (identified forest dependent communities) in each location; thus 150, 100, 100, 50 and 50 households were sampled from the rainforest, mangrove forest, Guinea Savanna, montane forest and Sudan Savanna zones respectively. Communities were selected from the respective states and research assistants in each of the area who understood the local languages were used for the study. Communities were selected based on information from local informants on their reliance on forest resources. Five communities were selected from each of the rainforest and mangrove forest areas, four from Guinea Savanna, three from montane and two communities were chosen from Sudan savanna ecozone. Communities were chosen using a random draw from all possible communities in the target areas. In each community households were randomly selected using the communities' roll calls. From the roll call, different households were selected at random intervals until the required number of households per community was reached. The consideration in the sample selection here was most importantly to get a representative and sufficient (not necessarily weighted) sample across the zones for the analysis. Structured questionnaires were administered on a one to one basis, with the household heads, or other family members who were familiar with forest resource use by the household and the wider community.

To check for interviewer bias and ensure data consistency and compatibility, the addresses and mobile phone numbers of each respondent was collected and information supplied by the interviewee randomly crosschecked in all zones by calling the respondents on their mobile phones. For any missing information on each questionnaire efforts were made to get back to the respondents in person or on phone to verify and complete them until 400 questionnaires were fully completed. The data collected were coded, screened and analysed using STATA statistical software. At the end of the screening 50 questionnaires were discarded for not having complete information required for the analysis and for lack of consistency and 400 were used for the analysis.

Table 3. Towns used for the study in each ecological zone

Ecological zone	State	Town
Mangrove	Bayelsa	Koroama, Okolobiri, Obuna, Polaku and Nedugo
Rainforest (Dense)	Cross River	Nsak, Okuni and Urban
Rainforest (Sparse)	Anambra	Isi Achina and Umuchu
Guinea Savanna	Plateau	Riyom, Mangu, Kanke
Montane	Taraba	Garin dogo Zau. Lushi garin dogo zau, Gang Bentsa-Dakka and Gani-Dogo Lau
Sudan Savanna	Katsina	Daddara and Jibia

1.8 Thesis structure

The thesis is arranged in six chapters. Chapter one is the introduction and background information about the research. The chapter introduces the research, looking at issues on climate change impact in relation to forest resource use in the Nigerian context. It highlights the problems and justification for the study, specifies the objectives and the hypothesis underlying the study, thereby setting the context for the research. All the references of chapters one and six are in the reference section at the end of the thesis.

Chapter two explores the response efforts of Nigerian policy makers to climate change impacts and the ethical consideration in climate change policy in Nigeria. This is in a form of a paper titled 'Nigeria's response to the impacts of climate change: developing resilient and ethical adaptation options' that has been published in the Journal of Agriculture and Environmental Ethics in 2011. In addition, the problem of resource use scarcity, security in relation to climate change were addressed with a resource use conflict model that has been developed for resolving resource use conflicts in Nigeria and West Africa and provide the theoretical framework for the thesis. This is presented in a paper that has been accepted for publication in African Journal of Agricultural Research titled 'Resource use conflict in West Africa: developing a framework for resilience building among farmers and pastoralists'. This is a conceptual chapter to put the research in perspective.

Chapter three presents the analysis of the levels of forest dependence in Nigeria and social perspectives of climate change impacts and adaption in different ecological regions of Nigeria. This is also presented in the form of a paper titled 'Climate change impacts and adaptation pathways for forest dependent livelihood systems in Nigeria' that has been published in the African Journal of Agricultural Research in 2014. This chapter addresses objective (i) of the research.

Chapter four focuses on the empirical estimation of the economic impact of climate change on forest resource use, using the Ricardian model. This is presented in a paper titled 'Assessing the economic impact of climate change on forest resource use in Nigeria: a Ricardian approach' and is currently under review in the Journal of Agriculture and Forest Meteorology. This chapter addresses objective (ii) of the research.

Chapter five assesses the perception of climate change and adaptation decision, determinants of adaptation strategies, benefit cost analysis and barriers to climate change adaptation. These are presented in three sections. The first is presented in a paper titled 'Climate change perception, awareness and adaptation decision among forest communities in Nigeria' and is currently under review in the journal of Mitigation and Adaptation Strategies for Global Change. The second section is also presented in a paper titled; 'Determinants of adaptation strategies to climate change in Nigerian forest communities', and is currently under review in the Regional Environmental Change. Section three is on benefit cost analysis and barrier to adaptation strategies in Nigeria. This chapter addresses objective (iii) of the research. This chapter addresses objective iv of the research.

In chapter six the findings of the research are summarized. In addition the conclusions and policy recommendation of the study are presented and areas for further work explored.

CHAPTER TWO

Status of Climate Change Policy and Forest Resource Use Challenges in Nigeria: Developing an Enabling Framework

2.1 Preface

Over 70% of the Nigerian population derive their livelihoods from agriculture and the forest (FGN, 2008), with the sector being crucial in the provision of food, income, raw material and employment. These resources are increasingly vulnerable to the impacts of climate change, particularly with a growing population and pervasive land use conversion. This suggests that there is a need for a robust and effective climate change policy and framework to address the adverse consequences and maximize the potential benefits of the forests.

Although some efforts has been made by Nigeria to assess the impact of climate change, a critical understanding of the nature of climate change, and its impacts on socioeconomic and geopolitical infrastructure in Nigeria, compared to the impending potential impact and what is obtainable elsewhere, is still rudimentary. The problem therefore is not as much the issue of lack of policy but that of lack of political will to pursue their logical and efficient implementation (Onyekuru, 2011; Onyekuru and Marchant, 2011).

In this chapter issues of poor policy framework and implementation, and the crisis resulting from resource use struggle are explored and suggestions and a framework for resource use conflict resolution in Nigeria that can be applied to other developing economies, developed. Importantly this framework sets up the theoretical and conceptual framework for this study and subsequent chapters. These issues are presented in two papers; the first on 'Nigeria's response to the impacts of climate change: developing resilient and ethical adaptation options' that has been published in the Journal of Agriculture and Environmental Ethics (Onyekuru and Marchant, 2011). The second paper is 'Resource use conflict in West Africa: developing a framework for resilience building among farmers and pastoralists' (Onyekuru and Marchant, 2014) has been accepted for publication in the African Journal of Agriculture Research.

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2.2 Nigeria's response to the impacts of climate change: developing resilient and ethical adaptation options

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Abstract

Global climate change will strongly impact on Nigeria, particularly on agricultural production and associated livelihoods. Although there is a growing scientific consensus on the impacts of climate change, efforts so far in Nigeria to deal with these impacts are still rudimentary and not properly coordinated. There is little evidence of any pragmatic approach towards tracking climate change in order to develop an evidence base on which to formulate national adaption strategies. Although Nigeria is not alone in this regard, the paper asserts that a National Climate Change Adaptation Strategy could help address this situation by guiding the integration of climate change adaptation into government policies, strategies and programmes, with particular focus on the most vulnerable groups and the agricultural sectors. There is an urgent need to adopt abatement strategies that will provide economic incentives to reduce the risk from disasters, such as developing agricultural practices that are more resilient to a changing climate.

Keywords: Agriculture, Environment, Livelihood, Policy, Sustainability.

Introduction

Nigeria has a population of 154 million people (Taylor, 2010) in an area of 923,768 km^2, characterized by physical and climatic diversity (Fig 1) and a wide variety of crops. Although famous for the crude oil resource, agriculture is strategic to the Nigerian economy; supplying food, raw materials for industries, earning foreign exchange, providing markets for the industrial sector and forming a key contributor to wealth creation and poverty alleviation (Federal Department of Agriculture (FDA), 2008). According to Adepide (2004), at the turn of Nigeria's political independence in October 1960, agriculture was the dominant economic sector, contributing about 70% of the Gross Domestic Product (GDP), employing about the same percentage of the working population, and accounting for about 90% of foreign earnings and Federal Government revenue. Today the case is different; according to Nigerian Tribune (2011) the crude oil sector accounts for about 80% of total revenue and 90% of foreign exchange earnings. Notwithstanding this change, the country is the world's leading producer of cowpea, cassava and yam. Agriculture continues to be central to the livelihoods of many Nigerians with more than 70% of the population deriving their livelihood from agriculture and agro allied activities (FDA, 2008). The agriculture sector accounts for 5% of total export, provides 88% of non-oil earnings, and contributes about 41% of the GDP, 85% of which is from the crop sub-sector (FDA, 2008). About 94% of the agricultural output is accounted for by small scale, subsistence farmers farming less than 2 ha (FDA, 2008). Such small scale contributions are particularly threatened by climate change due to low adaptation potential. Climate change also threatens Nigeria's fossil fuel dependent economy: globally efforts are focused on navigating global energy away from the "black gold". It will therefore become double tragedy if both agriculture and crude oil are impacted upon by climate change and Nigeria does nothing in time to adapt.

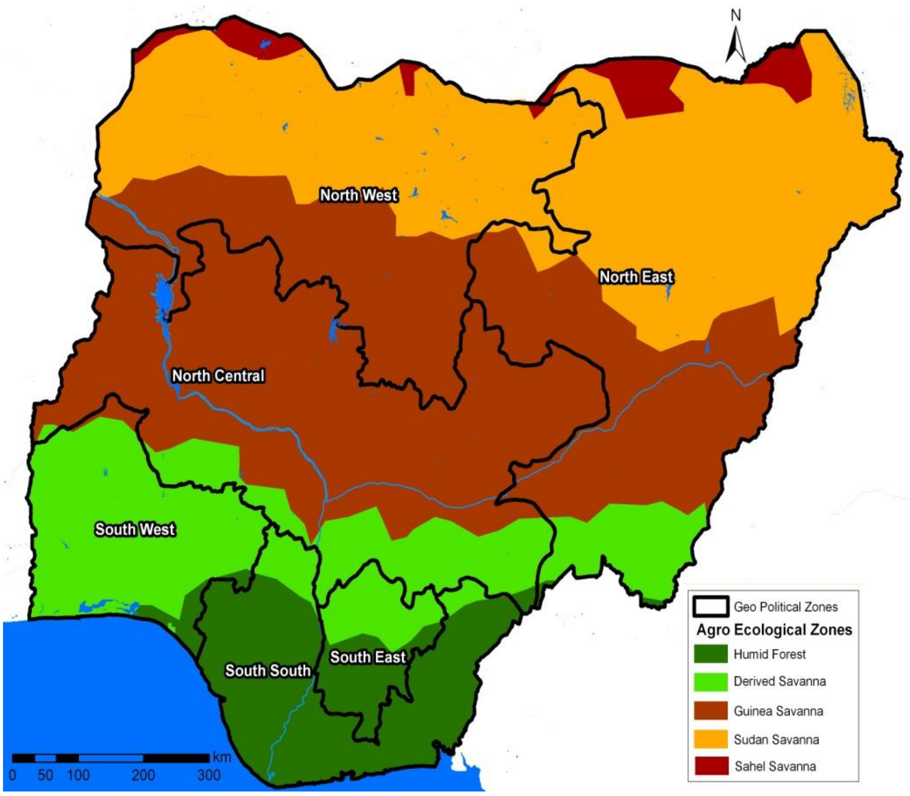

Figure 1. Agro Ecological Map of Nigeria showing different agro ecological and geopolitical zones

Many interactive processes (climate, soil, political process, culture, economic process, social amenities, institution and policies) determine the dynamics of food demand and supply. Agro-climatic conditions, land resources and their management are clearly key components that are critically affected by distinct socio-economic pressures, including current and projected trends in population growth, availability and access to technology and development (Fischer *et al*., 2005). Relatively small climatic shifts can trigger or exacerbate food shortages, water scarcity, and the spread of disease, human migration and natural resource competition (Podester and Odgen, 2008). Once underway, this chain reaction becomes increasingly difficult to stop. The impact of climate change–induced migration will be felt throughout Africa, but its effects in Nigeria pose particularly acute geopolitical challenges, both manifested by internal and international migration (Podester and Odgen, 2008). The first domestic migratory wave will likely be from agricultural regions to urban centres where more social services are available. Such a situation will exacerbate the risk of state failure as central governments lose control over some of their territory and their borders. The objective of this paper is to appraise the response of Nigeria to climate change impacts in the country through a review of the literature to assess how a sound, ethical environmental policy can be established; policies based on environmental sustainability and human welfare**.** It stresses the need for a more pragmatic approach to managing climate change impacts and calls on the Nigerian government to develop mitigation and adaptation options to avert the impending catastrophe, that climate change could impact on an oil centered, but agricultural dependent economy like Nigeria.

Vulnerability and Impact of Climate Change in Nigeria

Oisahoin (2008) reports that impacts on people and their livelihoods resulting from climate change is greater in Africa than in many parts of the world. On average the continent is 0.5°C warmer than it was 100 years ago (IPCC, 1996). Changing weather patterns are creating new complex emergencies where poorer countries that are affected by famine, drought and floods, are often accompanied by outbreaks of infectious diseases. Already Nigeria has experienced natural shift in the long-term rainfall mean towards more arid conditions (Ikeme, 2001). Such reports about climate change have to be viewed in the context of large uncertainties in current climate change projections due to gaps in climate change science, uncertainties over crop responses, in complex socio-economic relationships and in the lack of detail in current climate change and ecosystem models (Slater *et al*., 2007). However, there are very obvious changes in timing and duration of rainfall pattern with the Sudan Sahel region of Nigeria suffering a 3-4% decrease in rainfall per decade since the beginning of the nineteenth century (Mohammad 2008). Clear divisions between the rainy and dry seasons, when planting dates were pre-planned resulting in predictable and bountiful harvest are no more. Erratic weather conditions preclude the planning of agricultural activities in the country. Indeed, Nigeria's national capability for assessing, forecasting and planning for climate change mitigation and adaptation remains inadequate.

According to the (IPCC) 2007 the most vulnerable nations to climate change are those situated in Sub-Saharan Africa, and specifically those states that have recently experienced conflict - Nigeria belongs to both of these 'high-risk' categories. "The low adaptive capacity to adapt to climate change is largely due to the extreme poverty of many African countries, frequent natural disasters such as droughts and floods, a dominance of rain fed agriculture, as well as a range of macro- and micro-structural problems" (Boko *et al*. 2007). Significant constraints also include limited support for climate risk management in agriculture and a limited use for such seasonal forecast products particularly at the local level. Local adaptation particularly is minimal as the rural poor often have very limited diversification options available to them. Factors heightening vulnerability to climate change and affecting national-level adaptation include issues of local and national governance, civil and political rights and low levels of literacy.

Developing countries are more vulnerable to climate change than developed countries, because of the predominance of rain fed agriculture in their economies, the scarcity of capital for adaptation measures, their warmer baseline climates and their heightened exposure to extreme events (Parry *et al*., 2001). Thus, climate change may have particularly serious consequences in the developing world, where some 800 million people are undernourished (Slater *et al*., 2007). Of great concern is a group of more than 40 ‘least-developed’ countries, mostly in sub-Saharan Africa, where domestic per capita food production has declined by 10% in the last 20 years (Slater *et al*., 2007). Thus, climate change impact will aggravate the already ‘in crisis’ situation in some of these countries. Podester and Odgen (2008) asserts that West Africa suffers the greatest losses due to climate change; these amounting to between 36% and 44% of the losses for the entire continent and between 42% and 60% of agricultural regional GDP. According to Mendelsohn *et al* (2000) seven African countries (Nigeria, Sudan, Algeria, Cameroon, South Africa, Moroco and The Democratic Republic of Congo) are predicted to suffer the largest average losses (47%) in the agricultural sector, with Nigeria suffering the highest.

Nigeria will suffer from climate-induced drought, desertification, and sea level rise (Podesta and Ogden 2007). Already, approximately 1,350 square miles of Nigerian land turns to desert each year; forcing both farmers and herdsmen to abandon their homes (McCarthy, 2006). Mohammad (2008) reports that desert, which now covers about 35% of Nigeria's land mass, is advancing at an estimated 0.6kmyr^{-1} while deforestation is taking place at 3.5%yr^{-1}. The desert belt has moved from Maidugri to Kebbi, Kano/Kaduna to Sokoto; a distance of about 1200km westward and about 800 to 900km southwards, while the Savannah interface between desert and forest is observed to be now around Oyo, Osun, Kogi and Makurdi - 1200km shift to the south (Fig 2).

Figure 2: Location map of Nigeria

According to Ikeme (2001) potential impacts of climate change on Nigeria runs through the country's economic, social and environmental sectors. For example, the projected impact of climate change on electricity generation and hydroelectric dams due to impact of reduced water flows on energy production and supply causing severe disruptions to economic activities. This threat is made more acute as Nigeria relies heavily on hydroelectricity, which accounts for over 36% of its electricity energy budget (Ikeme, 2001). Electricity disruption impacts on commercial and social activities of the nation.

The social implication of environmental change for Nigeria is multidimensional. Nigeria will experience massive environmental refugee migration, particularly along the coastal region where an estimated 20 million people (22.6% of the national population) live (Ikeme, 2001). According to Podester and Ogden (2008), Lagos is one of the West African coastal megacities that the IPCC fourth assessment report (2007) identified as at risk from sea-level rise by 2015. The estimated number of people that would be displaced ranges from 740,000 for a 0.2-m rise to 3.7 million for a 1-m rise and 10 million for a 2-m rise (Awosika *et al*., 1992). Numerous economic activities are located within the coastal zone that will be seriously impacted upon. For example, coastal areas form the food basket of the region; estuaries and lagoons supporting industrial fisheries accounting for more than 75% of fishery landings in the region. The impact of climate and environmental change coupled with high population growth (Nigeria is the most populous nation in Africa, with 75% of the population under the age of 30) will result in significant migration that will further contribute to political and economic turmoil. A situation that is exacerbated by the lack of a pragmatic approach by the government to address the issue of population control coupled with inactivity regarding climate change adaption.

Efforts to understanding, mitigating and adapting to climate change

Several efforts have been made towards understanding and curbing the impacts of climate change; these will be considered at the international, regional and national levels.

Global level

The first World Climate Conference took place in 1979, however, it was not until 1988 that the United Nations gave serious attention to climate change in response to growing environmental awareness and concern for the consequences of the phenomenon (Adejuwon 2002). The UN General Assembly at its 43rd session in 1988, adopted Resolution 43/53 entitled, *Protection of global climate for present and future generations of mankind'.* The mounting evidence about the role of enhanced greenhouse gases and the potential consequences for climate change and human impacts, prompted 154 countries around the world to sign the United Nations Framework Convention on Climate Change (UNFCCC) in 1992. The UNFCCC Conference of Parties (CoP) is the highest decision-making authority in climate change responsible for keeping international efforts to address climate change (UNFCCC, 2011). Global action to address climate change is spear-headed by the UNFCC, the Intergovernmental Panel on Climate Change (IPCC) via agreements emanating from recent summits such as the Copenhagen Conference and the Cancun agreement. The IPCC is the leading international authority on climate change; it was formed by the World Meteorology Organization and the United Nations Environment Program to advise governments on the latest climate change science, its impacts and possible adaptation and mitigation responses. It publishes a major state-of-the-science and climate impacts report every five years (IPCC, 1990, 1995, 2001 and 2007). IPCC conducts global, regional and national climate change assessments to advise governments on the potential future state of the climate system. Current international agreements aim to stabilize atmospheric greenhouse gas concentrations at a level that would prevent dangerous interference with the global climate system (Ikeme, 2001).

Other global climate change mitigation and abatement schemes are the Clean Development Mechanism (CDM) and Reducing Emissions from Deforestation and Forest Degradation (REDD). CDM allows a country with an emission-reduction or emission-limitation commitment under the Kyoto Protocol to implement an emission-reduction project in developing countries. Such projects can earn saleable certified emission reduction (CER) credits, each equivalent to one ton of CO_2, which can be counted towards meeting Kyoto targets. The mechanism is seen by many as a trailblazer as it is the first global, environmental investment and credit scheme that provides a standardized emissions offset instrument (UNFCCC, 2011). In addition, the mechanism stimulates sustainable development in the developing countries, as well as emission reductions, while giving industrialized countries some flexibility in how they meet their emission reduction or limitation targets. REDD works on the principle that countries that are willing and able to reduce emissions from deforestation should be financially compensated for doing so (Parker *et al*, 2008). Previous approaches to curb global deforestation have so far been unsuccessful, however, REDD provides a new framework to allow deforesting countries to break this historic trend. REDD is designed to provide market and financial incentives for countries to reduce their greenhouse emissions from deforestation. REDD+ further extends REDD by including the role of conservation, sustainable management of forests and the enhancement of forest carbon stocks. These mechanisms for reducing GHG emissions and promoting storage of carbon drive and inform actions at the regional and national scales.

At the continental level

At the continental level Africa's Partnership Forum (APF) (2007) asserts that the G8 countries (Canada, France, Germany, Italy, Japan, Russia, United Kingdom and the United States) began to discuss the impacts of climate change in Africa in 2003, by agreeing to strengthen international co-operation on global earth observations with a view to developing fully operational regional climate centers in Africa through the Global Climate Observing System (GCOS). By financing the transition to cleaner energy, the World Bank and African Development Bank are jointly developing a framework to accelerate the adoption of cleaner, more efficient energy production and use (WB, 2007). The subsequent adoption of an 'Action Plan for Africa on Climate Information for Development Needs (or ClimDev Africa) is the culmination of a multi-year effort by the GCOS-UNECA-Africa Union partnership to address gaps in mainstreaming adaptation into policy.

African governments on the other hand are not relenting in their efforts to address climate change. According to Fleshman (2007) African leaders are aware of the continent's vulnerability and have long supported international efforts to combat the impact of global warming and climate change. African governments were prime movers behind the 1994 UN convention to combat climate change. Many African countries also were early signatories to the 1992 UN Framework Convention on Climate Change (UNFCCC) and the 1997 Kyoto Protocol, the first, and to-date only, international treaty setting binding limits on pollution emissions. But because Africa's small industrial base and limited transport system and power use the continent generates comparatively low level of greenhouse gases and thus, reducing emissions has not been top priority (Flehman, 2007). Instead African governments, civil society and their development partners are focused on planning adaptation strategies for the coming climate shocks and assisting vulnerable communities to diversify livelihood and resource basis.

The Climate for Development in Africa (ClimDev Africa) Programme, a joint initiative of the African Union Commission (AUC), the United Nations Economic Commission for Africa

(UNECA) and the African Development Bank (AfDB), formed as response to the urgent challenge that climate change poses to the advancement of Africa's development objectives. The issue of climate change impacts has been mandated at regional meetings of African Heads of State and Government, as well as by Africa's Ministers of Finance, Economic Development and Planning, and Ministers of Environment. More concretely, it is moving towards addressing the need for greatly improved climate data and information for Africa, and to also strengthen the use of such information for decision making by supporting analytical capacity, knowledge generation and sharing activities. Consultative Groups for International Agricultural Research (CGIAR) are also involved in developing capacities across Africa by sponsoring research and trainings for African scholars.

According to APF (2007) the African Union is also raising climate change adaptation as a key priority and seeks more support for adaptation and better integration of climate in development programmes. At its January 2007 meeting, the African Union called for the integration of climate change adaptation strategies into African national and sub-regional development policies and programmes and activities. It also demanded that developed countries undertake deeper cuts in GHG emissions and implemented the "polluter pays" and "differentiated responsibilities" principles as provided for in the UNFCCC. On financing, it called for the urgent streamlining of the Global Environment Facility (GEF) funding mechanisms to ease African countries' access to GEF financial resources; and the exploration of other financial resources and mechanisms to support Africa's adaptation programmes. The Commission of the African Union has also been working towards an African Strategy on Climate Change. The draft strategy document which has been a subject of series of consultations and review at various levels, is built on four interrelated themes, including (i) climate change governance, (ii) mainstreaming climate change in development, (iii) harnessing education, science, research and innovation for climate change, and (iv) promoting regional and international cooperation and partnerships in climate (Nwencha, 2011). According to Nwencha (2011) it was on the hill of the 17th Conference of the Parties to the UNFCCC (COP17) and the 7th Session of the Meeting of the Parties to the Kyoto Protocol (MOP7), coming up in November/December 2011, in Durban South Africa, that the African Union Commission organized the First Climate Change and Development for Africa Conference held 17th to 19th October, 2011 in Addis Ababa, Ethiopia, to articulate the African position for the meeting and form a united front to negotiate a better deal for Africa. The conference reiterated the support of African leaders for adaptation as Africa's foremost strategy to tackle the multiple effects of climate change on the continent, thus underscored Africa's commitment to climate change mitigation and adaptation.

Some African countries have developed paths to effectively dealing with climate change impacts. For example the South African government has developed the South African National Climate Change Response Strategy. This is a detailed South African study that has been compiled on a sectoral basis that identifies priorities for dealing with climate change in South Africa (Department of Environmental Affairs and Tourism, South Africa, 2004), also, Hpong (2011) reports that Ghanaian government has formulated a Climate Change Policy in 2010. The policy was hinged on seven main themes, Governance and Co-ordination, Capacity Building, Research and Knowledge Management, Finance, International Co-operation, Communication, Monitoring and Reporting and integrates climate concerns into the 2011 budget. This is an evidence of a pragmatic and sincere approach of a government's readiness towards climate change mitigation and adaptation.

In terms of funding there exist a plethora of donors involved in climate science and agricultural adaptation in Africa. The Department for International Development (DFID) funds 14 projects in Africa, such as Climate Change Adaptation in Africa (CCAA) It is a £24 million 5-year program which started in 2006. The Global Environment Facility (GEF), collaboration between UNEP, the World Bank and UNDP, provides grants to developing countries for projects that benefit the global environment and promote sustainable livelihoods of local communities. Assessments of Impacts and Adaptations to Climate Change (AIACC), was one of GEF's key initial adaptation programs. The research driven program started in 2002 and carried out twenty-four regional assessments. Also the United Nations Food and Agriculture Organization (FAO) has a widespread presence in Africa with a mandate of food security in member Countries, but the organization undertakes a range of activities relating to climate change adaptation (SEI, 2008)

According to SEI (2008), the Climate Systems Analysis Group (CSAG) at University of Cape Town (UCT) is the only African institution currently engaged in empirical downscaling activities for climate change modeling. No African climate research institutions are involved in producing GCM models, because of the lack of the necessary infrastructure, both human and equipment. Africa depends, to a very large extent, on institutions based in Europe and North America for its operational climate forecasting capacity. Three institutions - NOAA (National Oceanic and Atmospheric Administration, USA), UK Met Office/Hadley Centre (United Kingdom) and (Centre National de la Recherche Scientifique, France (CNRS) routinely make seasonal climate forecasts for Africa based on their respective GCM models. Among these the Hadley Centre, and their dynamically downscaled PRECIS model, is the most widely applied, across Africa. The Consultative Group on International Agricultural Research (CGIAR) and the Earth System Science Partnership (ESSP) in 2009 launched the Research Program on Climate Change, Agriculture and Food Security (CCAFS), a 10-year research initiative that seeks to overcome the threats to agriculture and food security in a changing climate, exploring new ways of helping vulnerable rural communities in sub Saharan Africa to adjust to global changes in climate. The African Technological Policy Studies Network based in Nairobi also engages African scholars on climate change issues through research and outreach programs. The Centre for Environmental Economics and Policy in Africa (CEEPA), located within the Department of Agricultural Economics, Extension and Rural Development at the University of Pretoria, has been running a project over the past few years that is working towards improve national and regional assessments of the economic impact of climate change on the agricultural sector of eleven African countries, and to determine the economic value of various adaptation options.

Despite these efforts and wide, and growing number of projects, there is very few evidence that agricultural decision makers have successfully drawn on climate change projection data to inform decisions that have improved agricultural productivity or human well-being. To address this "disconnect" between climate science and African agriculture, capacity capable of linking existing climate data and agricultural decision making needs to be created. This is as much an institutional challenge as it is a technical and human resource challenge and must be focused at a number of levels from the international to the national.

National Level

Within Nigeria some efforts to assess the impact of climate change, and to use this information for livelihood improvement have been made. A program entitled 'Building Nigerian Response to Climate Change (BNRCC)' has been implemented by the Nigeria Environmental Study/Action Team developed following an earlier initiative called the Canada-Nigeria Climate Change Capacity Development Project (CN-CCCD), implemented with funding from the Canadian International Development Agency. The goal was to build public awareness/understanding and support policies for optimal management of the impending climate change by developing capacity for a range of issues. Through a series of workshops, consultations and awards to intermediary organizations and research institutions, CN-CCCD worked to inform reach a range of stakeholders on issues on climate change and facilitated activities that enabled the country, in November of 2003, to submit its First National Communication to the Conference of the Parties (CoP) (UNFCCC, 2011). The Nigerian communication indicated that a significant proportion of the economy is dependent on climate-sensitive natural resources, that resource conflicts, exacerbated by climate change, are the greatest source of insecurity in Nigeria. The communication states that Nigeria's vulnerability to climate change mandates that the country evolve adaptive measures and contributes to international efforts in reducing emissions of greenhouse gases (Federal Government of Nigeria (FGN), 2003). National priorities include assessing the vulnerability of sectors to different climate change scenarios, to develop, assess and implement mitigation and adaptation options for climate change. Other priority areas include developing a legal framework, increasing public awareness, promoting research and building strong institutions and partnerships between the public and private sectors to cope with the impacts of climate change. Preparation of the Second National Communication is developing from a consultative process. A National Focal Point called the Special Climate Change Unit constitutes an Inter-ministerial Committee that was inaugurated following a roundtable committee discussion on climate change in August 2009 with action in progress to formulate a national policy on climate change. The senate approved in November 2010 the establishment of the National Climate Change Commission to coordinate efforts to tackle the adverse impacts of climate change in the country with the commission expected to be operational in 2011, but till now it is not yet operational. A critical look at understanding the nature of climate change, and its impacts on socioeconomic and geopolitical infrastructure in Nigeria, compared to the impending potential impact and what is obtainable elsewhere, are still rudimentary in Nigeria; just at the level establishment of committees and agencies, conferences, workshop groups and focus groups producing suggestions and papers. There is little clear evidence of concrete, proactive and pragmatic advances towards tracking climate change incidence and impacts, early warning, research, mitigation and adaptation. This gap was also identified by DFID (2009) in their assessment of Nigeria vulnerability to climate change. Key gaps include data on climatic trends, baseline assessment of natural resource and socio-economic conditions, data on incidence of extreme events such as drought, flooding and coastal flooding, and socioeconomic data at a local and regional level. In spite of these deficiencies, on a positive note, there is good academic capacity related to climate change expertise within Nigeria in various institutions, but co-ordination of this expertise and funding for research are lacking.

Nigeria’s engagement of individuals, NGOs and advocacy groups in combating climate change has not been impressive. The case of gas flaring is a litmus test for the level of preparedness of the government to mitigate climate change Nigeria is the world`s biggest gas flarer, a practice that costs Nigeria about US$2.5 billion annually (Environmental Law Alliance Worldwide (ELAW), 2006). Yet despite the campaign by environmental advocates like, Environmental Rights Action, Climate Justice Programme, Friends of the Earth International, Earth Rights International, Global Green-grant Fund and others for the country to end gas flaring, nothing tangible is being done. The government has not been powerful enough to enforce a ban on the multinationals oil companies.

Nigeria has had a lukewarm attitude towards climate change talks in recent time. According to Ekeanyanwu (2011) Nigeria's place as a leading negotiator for climate justice for the African continent has plummeted in international climate change negotiations such as that scheduled for Durban, South Africa in November/December 2011. Proceedings from the Bonn Climate talks showed that only one Nigerian was among the over 200 negotiators appointed as Africa's representatives, under the platform of the African Group. South Africa had 29 negotiators, Senegal 8; DR Congo 18, Algeria 7, Gabon 6, Ghana 6; Sudan 5; Kenya 5; Malawi 4 and many others. The absence of Nigeria from the global climate scene is embarrassing, particularly when the size of the country is very big and economic potentials are not being realized The recently designed Green Climate Fund, which had members from eight African countries (South Africa, Gabon, Egypt, Ethiopia, Morocco, DR Congo, Burkina Faso and Zambia), has no representative from Nigeria. Thus, Nigeria's voice is not being represented at vital global climate committees and discussions as a result of the lip service government have been paying to climate change (Ekeanyanwu, 2011). Although Nigeria has the potential resources and capacity in terms of policies, institutions and human capital, but does not suggest finance and infrastructure, to implement climate change mitigation and adaptation. If there is the political will to do so, Nigeria will soon be able to develop and implement climate change sensitive policies and development initiatives. Like Ghana, whose climate change policy is supported with clear budgetary allocation and implementation pathway, Nigeria should follow suit and especially in terms of utilizing the abundant human and natural resource potentials.

Discussion: urgent action required to maximize potentials

According to the IPCC (2007) report, Africa needs to focus on increasing adaptive capacity to climate variability and climate change over the long term. Reducing risks with regard to possible future climate change impact will depend on building stronger livelihoods to ensure resilience to future climatic shocks. Institutions must play a critical role in successful adaptation; developing and designing proactive rather than reactive strategies to enhance adaptation. Interventions, such as agricultural capital stock and extension advice, national grain reserves, grain future markets, weather insurance, food price subsidies, cash transfers, school feeding schemes, micro-financing and social welfare grants are just some of the tools that need to be used to enhance adaptation to climate change and mitigate impact of future shocks and stresses. The success of these mechanisms in overcoming such constraints can be enhanced if supported by local institutional arrangements developed on a long-term sustainable basis. These adaptive solutions should be mainstreamed into national development processes, with unprecedented collaborative efforts by governments, humanitarian and development agencies to find ways to move away from reliance on short-term emergency responses to food insecurity, to longer-term development-oriented strategies that involve closer partnerships with governments (IPCC 2007). Governments around the world are already implementing policies to mitigate or/and adapt to climate change impacts. For example, Okorie (2009) reported that American president, Barack Obama has ordered his energy secretary (Steven Chu) to find ways by which America can change its energy policies and depend less on fossil fuel. A range of steps, such as those outlined above, must be implemented in conjunction with an international shift to a low carbon future.

On the part of Nigeria, Oisahoin (2008) asserts that despite the fact that numerous policies relating to environment and climate cover numerous sectors such as environment, energy, agriculture, health, sanitation, gender, housing and urban development, many of these policies were formulated solely by the federal government using a top-down approach and lack proper implementation and enforcement. Furthermore, there is lack of proper coordination between these policies and the different economic sectors, which has limited the focus on climate change adaptation (Oisahoin 2008). The problem therefore is not as much the issue of lack of policy but that of lack of political will to pursue their logical and efficient implementation. This situation is made more worrisome by the lack of sufficient empirical evidence of the level of the nation's vulnerability to climate change, which will inform evidence based policies and programmes towards effective mitigation and adaptation.

A study by Mendelsohn (2000) identified serious deficiency in impact research, given the importance of efficient adaptation, presently, public infrastructure such as roads, long-term weather forecasts, and agricultural research and extension are inadequate to secure appropriate adaptation. There also lacks a system to criticality assess the impacts of policies and monitor effectiveness so that there can be feedback into developing new ones and appropriate policy. Thus, there is an urgent need for Nigerian government to develop a climate change tracking system (weather monitoring and early warning), develop and faithfully implement policies and regulations towards climate change mitigation and adaptation. Lending a voice to this call for action, Ogbonnaya (2009) asserts that climate change is an "unprecedented" threat to food security and calls for a "climate-proof" model of development and massive emission cuts to avoid "possibly cataclysmic change." Although climates across Africa have always been erratic, scientific research "indicate new and dangerous extreme" forecasts (Ogbonnaya, 2009).

Climate change is an overwhelming development issue across Africa, unless we take genuine steps now to adapt, the consequences will be enormous. There are a number of priority areas that form a framework on which to implement adaptation strategy. Firstly, high levels of poverty and low levels of human development limit the capacity of Nigeria to manage risks due to climate change. Health hazards and poverty imposes on the government the responsibility to take proactive remedial measures. Secondly, the need for public awareness and enlightenment cannot be over emphasized. Ebonugwo and Adegboye (2009) observed that the level of public awareness environmental issues and the need to develop sustainable living is very low. Even lower is public knowledge about climate change and available adaptation and mitigation measures. Such an awareness deficit on these critical threatening issues must be urgently and decisively addressed (Ebonugwo and Adegboye, 2009). Research on the nature of climate change and the socio-economic implications on Nigeria is necessary for developing adequate response strategies. Developing climate change science and its potential impacts on Nigerian agriculture, its people and the associated livelihoods is very important for both creating awareness, and providing the background information required for targeting policies. Indeed, lack of awareness on the part of policy makers is a major constraint to adequate forecasting and formulation of adaptation policies exacerbated by the paucity of climate data in Nigeria (Ebonugwo and Adegboye 2009). Findings from research on all dimensions of the climate change can be used to guide policy development and developmental trajectories. The developing world should feed into the CDM provision of the Kyoto protocol and emphasize the provision of substantial monetary aid and invest heavily in forestation schemes. The benefits; such as carbon sequestration, aesthetic appeal, biodiversity conservation (especially the endangered species), ecological and human welfare, though are construed with intrinsic values, are enormous and surely out-weigh the visible physical structures which many politicians are much more interested in and ensure investment in climate change mitigation and adaptation which will impact more on long-term sustainable development than immediate physical infrastructure that will fade away with the passage of time. Studies on national and regional climate change in Nigeria should be embarked upon and vigorously pursued in the short to medium term. The findings of such studies will be crucial for the formulation of adequate response and adaptation policies that are evidence-based and have the potential to engender long term sustainability.

From empirical evidence it is apparent that the African countries will bear the major brunt of a problem caused by global collective action of which they are the least contributor. Oil-producing countries should be compensated for their projected income losses in the event of the implementation of the Kyoto protocol and assisted in the diversification of their economy. Nigeria can only be able to ensure that her interests are protected in the emergent global abatement strategy if it increases its level of participation in international negotiations. With increasing globalization of markets means that Nigeria's competitive edge may be jeopardized if it fails to apply environmentally sensitive methods of energy extraction and consumption in its economic development. Increased government participation in global climate change deliberations in order to negotiate a better world trade deal for Nigeria and Africa is very necessary. Although Nigeria needs to do something pragmatic to address the impacts of climate change, this should be supported by the global community. According to United Nations Statistics Division (2010) Nigeria emits 95,272 metric tonnes of $CO_{2,}$ which account for about 0.32% of global emissions. This is very minimal compared to the world leading CO_2 emitters; China (22.30%), US (19.91%), India (5.5%), Russia (5.25%) and Japan (4.28%). Nigeria, will inevitably be subjected to the International climate change abatement measures, and should begin now to put adequate climate change abatement strategies and a regulatory framework in place.

Since over 70% of the Nigerian population derive their livelihoods from agriculture (FDA 2008) with the sector being crucial in the provision of food, income, raw material and employment, there is need to invest money from crude oil into the agricultural sector and evolve adaptation strategies to safeguard the sector and the nation state. These adaptations include such initiatives as the development of early warning systems to enable timely implementation of remedial measures, effective water use strategies and intensive research into energy usage. A central element of adaptation approach should be ecosystem management and restoration activities such as forestation, watershed rehabilitation, effective water harvesting and conservation. These focal areas should promote best practices that are climate change resilient in agriculture and fisheries, including promoting the use of cleaner energy sources. Better planning to reduce the risk from disasters, together with developing agricultural practices that are more resilient to changing climates would also help mitigate climate change impacts.

In as much as the developed nations should urgently and significantly cut down their emission levels, developing nations like Nigeria should at the onset embrace clean and renewable energy alternatives in their quest for economic growth. This though may be more expensive in the short run, but will pay off in the long run, as they will be compensated via the Clean Development Mechanism (CDM) instrument. For reducing its contribution to climate change, the mandate for Nigerian energy planners is to institutionalize its development of energy efficiency and renewable energy with appropriate goals and timetables for increase use in areas where grid extension is too costly and where opportunities for the use of renewable energy sources is economically warranted. This should be accompanied by an inbuilt mechanism for stock-taking and reassessment of progress so that targets can be implemented and success measured. In addition to building institutional framework, Nigeria should also adopt specific regulatory measures such as establishing comprehensive air quality standards and create national energy efficiency codes that have the potential to be the driving force for rapid development of the country's energy efficiency and renewable energy opportunities. Market transformation mechanisms, similar to that adopted in some developed countries, and how these will encourage more rapid development of its energy efficiency and renewable energy potential, should be explored. Such a shift in energy policy objective will obviously benefit from an increase in government-industry collaboration; a key avenue for development rarely explored in Nigeria's development initiatives. This is the most ethical, rational and justifiable thing to do. As the industrial nations are responsible for the vast majority of global pollution, these countries have the moral responsibility of funding global remediation expenses. Additionally, industrially advanced nations need to assist developing countries with funding and technical assistance to conduct environmental and economic impact analyses and establish sound environmental practices to protect the health of their citizens.

The problem with climate change science lies in its peculiar nature which is an obstacle in itself to our ability to act – common good, intergenerational and in most cases intangible with immeasurable benefits. Since climate change abatement strategies are under-pinned by a rationale of common good, individual countries will not make sacrifices for others continue to create their own wealth. Even if everyone is aware of the risk of abuse, the mix of selfishness, competitiveness and unregulated exploitation give little incentive to act – the tragedy of the commons. Every nation wants to act in its own interest but that may not be the same as the global interest. Since it is an intergenerational asset, the underlying rational economic structure focuses on maximizing present day utility before thinking of bequeathing to the unborn. Contemporary politicians and political structure dare to invest in intangible assets that are not readily visible and do not benefit their constituencies directly, especially when the need to showcase their achievements for re-election arises. The situation is made more complex when the question of who should pay arises. Thus, the developing countries are justified in their stand that developed countries that got rich by polluting should as matter of moral justification be made to pay for remedial actions globally, while developed countries that may not bear much of the burden of the impact are not making any significant progress in either cutting down emission or committed to remediation. The question of who will pay is at the center of climate change economics, which guides to a great extend the decisions of our politicians whether to act or not. The economics of climate change is full of risks and uncertainties and most politicians are not ready to invest into an uninsured risk. Economists and man generally is a rational animal, putting profit maximization in the fore of any investment analysis – thus, will it pay off, is always the question. So the inability to clearly answer these questions has been the bane of climate change abatement. If not how do we explain the reluctance of the U S and Russia to sign up to the Kyoto agreement.

Looking at it from another perspective, many scientists have shown that impact of climate change will be harmful, the questions are what harm? To what extent and to who? However, these are filled with uncertainties and definite answers that politicians and policy makers seek are often not available. In addition there is the lack of consensus about the best partway, extent and the best time, now or later to invest in climate change. So in reality no one wants to invest into oblivion. The science of climate change, no matter how advanced, will never be sufficient to tell humanity what to do. Science may be able to inform policy by forecasting how severe climate change will be. In the case of Nigeria there is a very big gap in the science of climate change. Economically, the country may not be able to confront the problem and politically there has not been any willingness to act right. Could the lack of willingness to act be justified on the table of ethics? That is, it is not their responsibility to act as they did not cause the mess. However, experience teaches that science alone is never enough. Political will may not also be enough when confronting environmental challenges, considerations of fairness, equity and justice must also inform any successful implementation of any abatement strategy. Science, politics and ethics have to form a policy synergy for us to address climate change and do what is right, regardless of the economics and the question of who was wrong or who gains.

Conclusion

Climate change impacts in developing countries such as Nigeria are a long-standing global issue and involve complex interactions between demographic, climatic, environmental, economic, health, political, institutional, social and technological processes. Science, economics, and philosophy have to combine to form a cohesive alliance (Brandolino, 2010) to enable a solution to be crafted that can have the required equitable and lasting impact. For Nigeria to achieve sustainable agricultural productivity in the face of the climate change there has to be an alliance among all sectors and disciplines in the economy. The problem with Nigeria is not that of lack of policies, institutions and regulations, but the lack of government initiative for policy implementation, lack of sufficient empirical evidence regarding Nigeria's vulnerability to climate change and the lack of appropriate mechanisms to assess the impact of existing policies.

Nigeria cannot afford to continue ignoring the potential impacts of the global climate change and the impact on its oil-based economy. Although Nigeria should capitalize on the emission concession afforded it for its low historical contribution to the climate change problem, it must introduce measures to reduce its greenhouse gas emissions, develop and apply more sustainable renewable energy alternatives to abort the negative impacts of climate change on its economic, social and environmental resources. It is imperative that the Nigerian economy be diversified and steered away from fossil fuels both in terms of production and consumption. An ethical policy needs to address sustainable development through ecosystem management that requires a change in human values and economics. Three core values that need to be addressed in policy making are protection of human health, sound ecological practices and resource sustainability. Climate change abatement should be a concern to the nation, its resources and interaction with the world. Stewardship of the planet is a moral task which demands us to do what is right; what is right will engender future long term environmental stability. For Nigeria to maximize the potentials and take advantage of new opportunities that climate change will bring for national development, politicians must take the lead and reverse an inactive approach regarding to the impact of climate change.

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2.3 Resource use conflict in West Africa: developing a framework for resilience building among farmers and pastoralists.

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Abstract

Resource scarcity and security are interconnected. The impact of recurrent resource degradation in West Africa is assessed, in conjunction with social and economic factors, showing how these have interacted with conflict in West Africa and its import in other conflict climes. Resource scarcity interacting with economic pressure and political instability, have resulted in the rapid loss of arable lands in the Sahelian region of West Africa, leading to social crisis across the region. Combined, these factors result in increased land use and social pressure and resultant ownership struggles, which generate conflicts in the southern Sahel. Evidences of resource scarcity and resource use conflict across the region are reviewed and analyzed. These interactions are used to develop a resource use conflict pathway model for building resilience among stakeholders in the region. It is suggested that by making more arable land available through land restoration, in combination with implementing poverty alleviation programmes for the resource poor, more sustained solutions to the socio-economic and resource crisis in West Africa and across the world could be achieved.

Key words: Climate change, Desertification, Economic pressure, Land restoration, Migration, Model, Ownership struggle, Poverty, Resource degradation, Security, Vulnerability.

1.0 Introduction

According to United Nations Economic Commission for Africa (UNECA) (2008), widespread poverty, dependency on climate-sensitive rain-fed agriculture, poor infrastructure, high dependency on natural resources in combination with conflict render West Africa vulnerable to impacts of drought and desertification. Land degradation and desertification are a major cause of forced human migration that can result in conflict, particularly where natural resources are scarce. Ensuing food insecurity, habitat destruction, socio-economic instability, poverty and feedbacks to enhanced climatic variability through land cover change can occur.

Experience have shown that the more people are dependent on sensitive forms of natural capital, and the less they rely on economic or social forms of capital, the more at risk they are from climate change and thus the more likely that they will be provoked to conflict when such resources are threatened (Barnett and Adger, 2007). Stern (2006) referred to how conflict may arise under certain circumstances, mainly as a result of forced migration, which is suggested to affect up to 200 million people globally by 2050. Blench (2004) asserts that the pressure on arable land in the semi-arid zone increased, soil fertility inevitably decreases making farmers to move to regions of uncleared bush or to increase the area of their land holding, excluding the mobile pastoralists who traditionally treated uncultivated bush as common resource. It is these interconnections of resource use, socioeconomic and environmental variable that this paper assesses within the context of West Africa.

The paper reviews evidence for climate change impacts on resource use and social interactions in the context of the West African Sahelian region. Interconnections are used to develop a conceptual framework (model) that can be used to understand the interactions between climate change, anthropogenic variables and resource use conflicts in Nigeria and West African sub region. The paper answers the certain critical questions: What are the likely resource use conflicts situations in West Africa? What are the predisposing variables for resource use conflicts in West Africa? How are the variables interacting to cause conflict? What are the adaptation pathways that lead to vulnerability and which pathways build resilience to conflict? How are these interactions linked to build a conflict management framework in West Africa and around the world? Answering these questions will offer useful insight to the social, economic, environmental and biophysical linkages and how different intervening variables can lead to different resilience outcomes in natural resource conflict management process, especially in environmental resource dependent and developing economies. Thus, offering useful tools to conflict practitioners, policy makers and social and political scientist in natural resource conflict management across the world.

The paper adopts the method of extensive literature review on the different areas relevant to resource use conflict process and useful in building a framework for conflict management especially among farmers and pastoralists across scale. These information are used to develop a resource use conflict management framework for natural resource dependent systems, thereby providing a veritable instrument in the hands of practitioners for present and future conflict management across the globe.

2.0 Conceptual and Theoretical Framework

In this section we present some of the conceptual issues and theoretical foundation relevant to the development of a resource use - conflict framework for conflict management in West Africa and other environmental resource dependent economies.

2.1 Conceptual framework

2.1.1 Resource scarcity

Resource scarcity refers to a situation where renewable resources are degraded or decreased or a situation of inequitable distribution of resources within a country or region (UN Interagency Framework Team for Preventive Action (UNIFTPA), 2012). Gendron and Hoffman (2009) opine that resource scarcity can be conceptualized in three ways; the basic human security, if the human population cannot meet its basic dietary requirements. This is also referred to as the minimalist approach; the absolute minimum of resources required sustaining human life. A second interpretation can be defined as current resource availability to meet rising or projected increased demand. A resource in this scenario is considered scarce if there are insufficient resources to meet projected demands. The maximalist approach considers both human and non-human demands on a particular resource (Matthew, 2008). Resource scarcity can also be conceptualized as one of three structural components:

- Supply induced scarcity, in which environmental degradation occurs;
- Demand induced scarcity in which there is increased consumption of a commodity; or
- A structural scarcity in which infrastructure and distribution mechanisms unevenly redistribute the resource in question or access is restricted (Homer-Dixon,1994; 1999; Kameri-Mbote, 2004; UNIFTPA, 2012).

2.1.2 Conflict

Several scholars have offered different definitions of conflict: in terms of status, Park and Burges defined it simply as the struggle for status (Bartos and Wehr, 2002). Mack and Snyder (1973) defined it as the struggle for scarce resources and significant social change. In terms of struggle for scarce resources; it has been generally seen as a situation in which two or more parties strive to acquire the same scarce resources at the same time (Wallenstein, 2002). Coser (1913-2003) defined conflict as a struggle over values and claims to scarce status, power and resources in which the aims of the opponents are to neutralize, injure, or eliminate their rivals. Bartos and Wehr (2002) define conflict as stemming from the desire to achieve incompatible goals and / or to express their hostilities; it is the pursuit of contrary or seemingly incompatible interests – whether between individuals, groups or countries (DFID, 2006). Conflict arises from the interaction of individuals who have partly incompatible ends, in which the ability of one actor to gain his ends depends on an important degree on the choices or decision another actor will take (Olufemi and Samson, 2012). For the purpose of this work we will define conflict simply as a (constructive or destructive) disagreement between groups, arising from incompatible goals on the mode of allocation of (usually but not limited to common) resources.

2.2 Theoretical framework

2.2.1 Conflict theory

The basic insight in conflict theory is that human beings are sociable but conflict-prone animals. Life is basically a struggle for status in which no one can afford to be oblivious to the power of others around him and individuals' behavior is explained in terms of their self-interests in a material world of threat and violence (Collins, 1974). Conflict theory looks at society as being made up of individuals or groups who must compete for social, political, economic and material resources (Fig.2). Marxists argue that economic inequality is at the heart of all societies. Thus, in basic terms, some people will have more than their fair share of society's economic resources and other will consequently have less than their fair share. Collins (1974) looks at people as animals maneuvering for advantage, susceptible to emotional appeals, but steering a self-interested course toward satisfactions and away from dissatisfactions and each individual is basically pursuing his own interests and there are many situations, notably ones where power is involved, in which those interests are inherently antagonistic and the dominant party take advantage of the situation. This need not involve conscious calculation, but a basic propensity of feeling one's way toward the areas of greatest immediate reward, like flowers turning to the light (Collins, 1974). Collins conclude that there is conflict because violent coercion is always a potential resource, and it is zero-sum sort, any use of coercion, even by a small minority, calls forth conflict in the form of antagonism to being dominated. In summary, every individual tries to maximize his subjective status according to the resources available to him and to his rivals.

Specifically, Hardin's *tragedy of the common theory* (Hardin, 1968) holds that indigenous common land tenure system in Africa encourages the degradation of the resource as a result of many individuals using scarce resource. Homer-Dixon (1991, 1994, 1995, and 1999) *environmental scarcity theory* links tension between parties as resulting from the growing vulnerability and insecurity of their livelihood, he argues that environmental change, population growth and unequal social distribution are the three main source of scarcity that lead to conflict (Homer-Dixon, 1994)

2.2.1.1 *Rationale for conflict*

The main reasons why conflict exists in resource distribution are:

- people believe they are treated unjustly,
- people do not have enough to live a decent life (absolute deprivation) or
- people may have belligerent culture (Bartos and Wehr, 2002).

Absolute deprivation occurs when a party is deprived of whatever it needs to lead a decent life, leading to a sense of frustration. Dollard *et al*. (1939) opine that frustration is a free floating hostility that can targ*et al*most anything at any time. People feel frustrated and get hostile whenever they are prevented from reaching their goals. They argue that whenever individuals get frustrated and are not able to vent it through aggressive actions, the feeling of frustration continues and become very intense that they can attack any person or group that is handy even if it is not the source of their frustration. So, coercion and the ability to "force" others to behave a certain way are the primary basis of conflict (Lepird *et al.*, 2012). Therefore, the basic principle of conflict theory is that the natural evolution of societies is described as a series of clashes between conflicting ideas and forces that at the end of each clash, a new and improved set of idea emerges; change needs conflict in order to be facilitated. This is known as the dialectical process (Olufemi and Samson, 2012).

2.2.1.2 *Causes of conflict*

According to Newton's physical theory of motion, each action produces a reaction, same is the case in the social theory of conflict as is depicted in Kant and Hegel theory (Bartos and Wehr, 2002), that every individual, group, organization or unit in society represent a force whose action stimulates many counter forces, and when forces meet counter forces it either stimulate cooperation or conflict depending on many factors (Bartos and Wehr, 2002).

There is ample evidence to show that scarcity (crop failure, common wells, common lands) has always been an elementary and ever present condition of existence in human history which leads to conflicts and wars (Baechler, 1999, Hilyard, 1999). Hence, Shetima and Tar (2008) opine that conflict over scarce environmental resources form an intrinsic part of dialectical interaction between human beings and nature and has been endemic in those areas where the environment, economic and social conditions have combined to predispose the two groups to a competitive encounter (Fig.2).

However some post-modern scholars question the notion of scarcity and argue that it is a matter of human definition and man-made phenomenon, connected to factors such as power, distribution, drawing of boundaries and international politics. Even though there may not be a cause – effect relationship between conflict of interest in resource use, competition and conflict, Shetima and Tar (2008) opine that the likelihood is increased with scarcity of resources upon which the groups depend. Thus, our recognition of socially generated conflict (insufficient necessities for some people and not for others) is not to deny absolute scarcity (insufficient resources), no matter how equitable they are distributed (Hilyard, 1999).

In the case of Nigeria conflict arises between pastoralists and farmers as a result of early southward movement of herders in the sedentary zones before the harvest is complete. And this farmers – pastoralists' conflict is mostly acute around the semi-arid zones due to the frequency of shortage of rains (Scoons, 1995). In Mali's Niger River delta, conflict between the farmers and the herder occur whenever the delta is drier and the farmers are forced to cultivate deeper parts of the delta, encroaching into the grazing areas, which angers the pastoralists (Moorehead, 1989). In Nigeria, due to shifts in planting techniques driven by changing climate, many farmers now plant over designated grazing routes long agreed upon with herders, leading to violence (Sayne, 2011).

2.2.1.3 *The conflict process*

Four important conditions influence the likelihood that resources will be the object of conflict:

- the degree of scarcity;
- the extent to which the supply is shared by two or more groups;
- the relative power of those groups; and
- the ease of access to alternative sources (Ehrlich *et al.*, 2000)

So depending on what the situation is and the mix of variables, the nature of conflict and the resilience of the people will vary. According to Tamas (2003), conflict is generated by the scarcity of natural resources in two primary ways. The first mechanism is that resource scarcity drives elite to “capture” resources, marginalizing powerless groups in the process. The second way scarcity supposedly causes conflict is through its debilitating effect on economic and social innovation – the “ingenuity gap” (Homer-Dixon, 1999), in which case the society is unable to utilize resources due to their lack of technical-know-how to exploit the resource. In their analysis of resource use conflict process, Ehrlich *et al.* (2000) opine that scarcities of renewable resources (such as cropland, fresh water and forests), due to their increased demand and/or their unequal distribution lead to their degradation and depletion and thus produce civil violence and instability by generating intermediate social effects, such as poverty and migrations, that analysts often interpret as the conflict's immediate causes. As a result powerful groups capture valuable environmental resources ("resource capture") and prompts marginal groups to migrate to ecologically sensitive areas ("ecological marginalization"), which in turn reinforce environmental scarcity and raise the potential for social instability. Should the migrants try to harness forest resources in their new location, there is the potential for resistant from the settled communities leading to conflict.

Societies can adapt to environmental scarcity either by using their indigenous environmental resources more efficiently or by decoupling from their dependence on these resources, depending upon the supply of social and technical "ingenuity" available in the society. If on the other hand adaptation is unsuccessful, environmental scarcity constrains economic development and contributes to migrations, situations which sharpens existing distinctions among social groups, weakens states and in turn makes them vulnerable to ethnic conflicts, insurgencies and coups d'etat (Ehrlich *et al.*, 2000). These two concepts - adaptation and vulnerability are the key cornerstones of our conflict pathway model in this paper (Fig.2).

2.2.1.4 *Resource scarcity and conflict*

Several scholars have linked resource scarcity to violent conflict, starting with the work of Thomas Malthus in his Essay on the Principle of Population (1798) and the Neo-Malthusianism

(Hardin, 1968; Homer-Dixon, 1994; Renner, 1997; Kahl, 2006; Ban, 2007). In his essay, Malthus claimed that the human population grows exponentially, while the supply of food only grows, at best, in an arithmetic ratio. This was believed to inevitably lead to subsistence crises. In his article, ‘The Tragedy of the Commons,’ Hardin (1968) picks up the Malthusian thread by using medieval grazing commons as a metaphor for problems of collective behaviour and use of resources (Theisen, 2006). He warns that what is seen as individually rational, in terms of resource consumption, always points in the opposite direction of the public interest. Homer-Dixon (1999) sees population growth as the main cause of scarcity. Neo-Malthusianism agree that there is scarcity of renewable resources that acts as important constraints on human behaviour, and that there are linkages between this and violent conflict. Since these areas are often densely populated, neo-Malthusians argue that this will lead to large-scale migration, which in turn spurs conflict (Homer-Dixon 1999; Renner 1997) (Fig.2). They also argue that environmental degradation is often following a non-linear pattern, making substitutions and preventive measures hard to apply (Homer-Dixon 1999; Kahl 2006). In particular, Homer-Dixon (1994, 1999) argues that decreasing access to renewable resources increases frustration, which in turn creates grievances against the state, weakens the state and civil society and increases the opportunity for instigating an insurrection.

Several studies provide evidence that environmental scarcity is the cause for many recent conflicts. Perhaps Barbier and Homer-Dixon’s efforts to link environmental scarcity and conflict through the inability of resource-poor countries to adapt to economic conditions and pressures offer, however, a clearly testable hypothesis linking resource scarcity to conflict (Tamas, 2003). Another effort to test the proposition is the work of Hauge and Ellingsen (1998), who found a positive effect of environmental degradation on conflict, particularly at lower levels of violence. Also UNEP (2009) found that natural resources play role in 40% of all violent intrastate conflicts. Study by the Toronto Group’s Environmental Change and Acute Conflict Project (ECACP) and the Environmental Conflicts Project (ENCOP) at ETH Zurich, found a link between violence in South Africa, the insurgency in Assam, and the Zapatista rebellion in Chiapas (Homer-Dixon, 1991, 1994, 1999; Homer-Dixon and Blitt, 1998; Percival and Homer-Dixon, 1998), Rwandan genocide (André and Platteu 1998; Bächler 1999; Ohlsson, 1999), ethnic clashes in Kenya (Kahl 1998; 2006), the conflict between Israelis and Palestinians (Homer-Dixon 1994), the civil war in Sudan (Suliman, 1993), as well as the Middle East and Nigeria (Spillmann, 1995; Bächler *et al.*, 1996; Bächler, 1998) and environmental degradation (Theisen, 2006; Bernauer *et al.,* 2011). In their work on rainfall as an instrument for economic shocks in Sub-Saharan economies, Miguel *et al.* (2004) measure deviations in precipitation and conclude that negative deviation increases the risk of conflict. They conclude that the recruitment cost of rebel soldiers decreases when there is low agricultural output. Lagged percentage change in rainfall, relative to the previous year, was found to increases the risk of onset of conflicts in Sub-Saharan Africa (Hendrix and Glaser, 2005). Raleigh and Urdal (2005) found a significant relationship between freshwater availability per capita and conflict. Also rainfall deviations above a certain threshold heighten the risk for the outbreak of civil war between 1980 and 2002 (Levy *et al.*, 2005). Of the 37 cases of communal clashes reviewed by Fasona and Omojola (2005) in Nigeria, 19 were triggered by land resource issues. Corroborated by Nyong (2007), who in his study, found that resource use conflict accounts for about 54% of all communal clashes in Nigeria. This is more prevalent when individuals are forced to migrate from the area of scarcity to other areas of perceived abundance. To this end, Suhrke (1993) contends that whether or not resource scarcity induced migration leads to conflict in receiving areas depends on the capacity of the state to accommodate the needs and alleviate the grievances of the migrants and locals alike. Thus, linking conflict to the socio-politico-economic system (Fig.1)

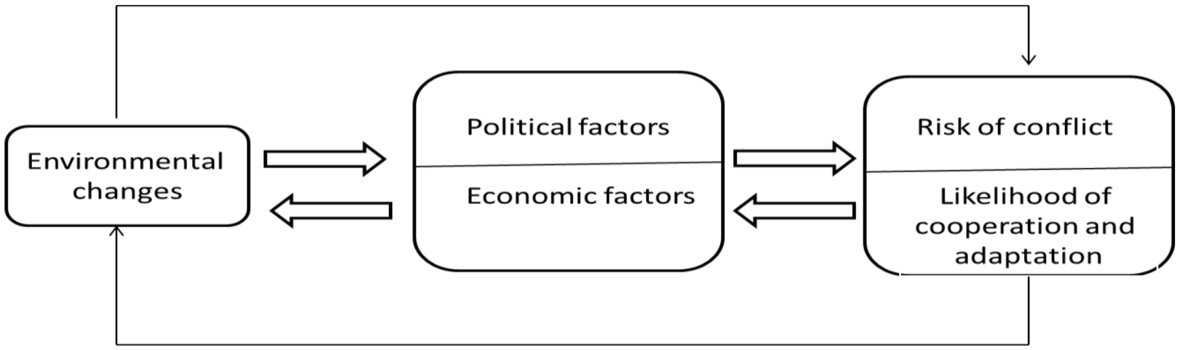

Figure 1. Indirect effects of resource scarcity on conflict and cooperation
Source: Adapted from Bernauer *et al.* (2011)

Theisen (2006) asserts that the most profound arguments for linkages between scarcity and conflict have been put forward by Homer-Dixon (1991; 1994; 1999; Homer-Dixon and Blitt 1998). He argues that rural-to-rural migration, motivated by scarcity in the place of departure, leads to further ecological and economic decline at the landing spot. This is either because the newcomers do not have sufficient local knowledge to treat the local ecosystems properly and/or that the ecosystem is especially vulnerable, leading to over exploitation and irremediable damage to the renewable resources. This process is labeled environmental marginalization and is argued to have caused deprivation conflicts in Chiapas (Mexico), the Philippines (Homer-Dixon 1999) and in the Brazilian Amazon (López, 1999).

Overall, the existing evidence suggests that resource scarcity may, under specific circumstances, increase the risk of violent conflict. In most cases as is in agreement within scarcity literature, the conflict potential of scarce resources is most relevant for less developed countries as their dependence on them is greatest (Bächler, 1999; Diamond, 2005; Gleick, 1989; 1993; Homer-Dixon, 1991; 1994; 1999; Homer-Dixon and Blitt, 1998; Kahl, 1998; 2006; Myers, 1993; Ohlsson, 1999; 2003; Petzold-Bradley *et al.*, 2001; Renner, 1997; Suliman, 1993). In poor societies where many people already live on the margin of subsistence, the effect of increasing scarcities will be increasing inequalities leading to factional conflict over government (Theisen, 2006).

3.0 Climate change impacts on natural resources in West Africa

Evidence have shown that the long-term decline in rainfall from the 1970s has caused a 25–35km southward shift in the Sahel, Sudan and Guinean ecological zones of West Africa (Gonzalez, 2001); resulting in the loss of grassland / acacia woodlands and shifting sand dunes in the Sahel (ECF and Potsdam Institute, 2004). In Nigeria for example there was a 425% increase in the extent of sand dunes/aeolian deposits between 1976 and 1995 around the northern axis of the country; desert now covers about 35% of Nigeria's land mass (Fasona and Omojola, 2005); this southerly migration of arid land results in Nigeria losing 3509km^2 of rangeland and cropland to desertification each year, particularly affecting eleven northern states (Brown, 2006). According to Okpi (2010), about 200 villages in Yobe State, towards the northern border of Nigeria with Niger Republic, have been incorporated within the Sahara desert. In Yobe and Gombe States alone, over 60,000 hectares of farmland have been lost to desertification; aerial photographs show that 30,000 hectares of productive land have been occupied by the encroaching dunes during the last quarter of the 20th century, removing grazing lands from 30,000 head of cattle year^{-1} (Olori, 2002). Between 50% to 75% of land areas in the northern states (which account for about 43% of Nigeria’s land mass) are affected by desertification and are particularly vulnerable to soil degradation (Yusuf, 2009). Yusuf (2009) showed that with a conservative production figure of 100kg of millet hectare^{-1}yr^{-1}, that the 60,000 hectares destroyed by the dunes in Yobe state Nigeria is capable of producing over 60,000 bags of millet; with an average grain requirement of one bag of 100kg of millet per family of four people per month, this loss would have been sufficient to sustain 20,000 people per year.

Furthermore the rate of forest conversion is spatially quite variable with some regions in Nigeria, such as the Mandara Plateau mosaic, Cross-Niger transition forests, Jos Plateau forest-grassland mosaic and the lowland forests, having more than a 95% transformation rates (UNECA, 2008). Between 1980 and 2005, up to 3.3% of West African forests were lost to exploitation due to high dependency of national and domestic economies on available natural resources (Atta-Asamoah and Aning, 2011). The implication of a continuous depletion of the sub-region’s forest through deforestation is increasing expansion of desertification which has serious implications on the patterns of migration between the Sahel and forest areas of the sub-region (Atta-Asamoah and Aning, 2011). The movement of people southwards has resulted in loss of primary forests and woodlands, repeated logging and clearing of land for agriculture. One of the biggest impacts on the forest has been the extraction of trees for charcoal making (about 150 million tons year^{-1} from the savannah and woodland areas), and the use of high-value woods for timber, most affected are *Dalbergia melanoxylon*, *Khaya spp* and *Pterocarpus erinaceus* (UNECA, 2008).

The situation in Nigeria is also reflected in adjacent West African countries, as major urban centres such as Accra, Kano, Niamey, Nouakchott and Ouagadougou are located within areas most affected by the observed changes in climate (UNEP, 2011). In Ghana about one third of the land area is threatened by desertification (UNEP, 2008) and Ghana's savanna areas have been increasing at an average rate of 1.2% per year from 1972 to 2000 (Idinoba *et al.*, 2010). The main area where resource scarcity could challenge political and economic stability in Ghana is managing the north-south divide where water is needed for the production of energy in the south and to support agriculture in the north; the cocoa production being vital for economic stability. In Niger, about 65% of the territory lies within the Sahara Desert, it is estimated that the desert is expanding by about 200,000 hectares annually (Mongabay, 2006) and it's forests are also shrinking; Niger has lost some third of its forests since 1990 (UNEP 2008). In Burkina Faso desertification is one of the key drivers behind 60% of recent urban population growth (UNCCD, 2004). Longer dry seasons are already driving farmers to migrate from northern and central parts of the country into the fertile east and west, bringing them into contact with settled farmers (Brown and Crowford, 2008).

A report by MECV and SP/CONEDD (2006) shows that drought, land degradation, deforestation and the partition of water between Burkina Faso and Ghana will be a delicate issue in coming years, especially if climate change leads to significantly lower rainfall and run-off. Together Ghana and Burkina Faso share 85% of the Volta basin and much of the Volta's flow travels through Burkina Faso before reaching Ghana (Brown and Crowford, 2008). The Volta contributes 56% of inflows into Dams in Ghana and produce more than 90% of Ghana's electricity (Filho, 2011). Thus, any decline in water level will impact directly on energy production in Ghana. The Senegal River has its main source in the Fouta-Djalon Mountains in Guinea and provides water to the semi-arid parts of Mali, Senegal, and Mauritania. Eight severe drought events have occurred during the period from 1970 to 1980, leading to chronic rainfall deficits. In 1988 and 2000, real crisis led to the consequent loss of lives in both countries (Trans boundary Freshwater Dispute Database, 2000). The Niger River basin, spreads over ten countries. Niasse (2007) asserts that there is the risk that water conflict could be blamed on upstream countries for what is really the fault of climatic change. Brooks (2006) suggests that the Tuareg rebellion in Mali 1990 began amid famine and widespread political repression despite being portrayed as an attempt by various Tuareg groups in Niger and Mali to secure an autonomous Tuareg state. Thus, a major impact of climate change in West Africa that is impacting on international relations is that on the trans-boundary water resources.

Lake Chad crosses four countries, with the biggest share located in Chad, then Nigeria, Niger and Cameroon. In 1960 it covered 45,000 km^2 but now only 550km^2 (Urama and Ozor, 2010; Filho, 2011). Lake Chad provides a lifeline to millions of people living in the catchment area; for sanitation, drinking, agriculture, fishing and religion / cultural activities, further shrinkage of the lake resulting from climate change will undermine the very base of human development in the basin, including in the north-east zone of Nigeria. Many villages have sprung up in areas where the lake has disappeared; these have been causing tension among the different countries with arguments over territory between various right claimants (Urama and Ozor, 2010). As the water of the lake recedes, farmers move closer to the lake's shoreline to cultivate the emerging lands and pastoralists move closer to the remaining water to feed their livestock, accentuating the rate of contact between major livelihood systems and thus sowing the seed of competition and conflict (Onuoha, 2010). More fundamentally, international boundaries of the lake has been blurred in the region, Nigerians and Nigeriens have crossed political borders in pursuit of the receding waters, as well as the migration of citizens of Chad further south in search of optimum opportunities. These long-distance migrants have been well-armed since the mid-1990s and are willing to use violence to assure their grazing (Blench, 2004). Most fishermen have converted to farming, but this may not be sustainable, as with less rainfall agricultural areas need water to irrigate their crops, and they will continue draining what is left of Lake Chad. The problem is expected to worsen in the coming years as population and irrigation demands continue to increase.

The risk of conflict degenerating into inter-communal clashes in the region could manifest in the near future if existing political institutions fail to reconcile conflicting interests over access to such shared water resources and in a situation where governance institutions concerned are weak, inequitable water management can heighten (Onuoha, 2008a: 2008b). This situation is not just in West Africa, a recent United Nations report reveals that more than 600 lakes in Africa are declining rapidly owing to the combined impact of climate change and resource overuse (UNEP, 2006). Also, water scarcity is already known to afflict 300 million people and claim at least 6 000 lives annually in Africa (Integrated Regional Information Network (IRIN), 2004).

4.0 Resource scarcity – conflict pathway model; the theoretical link

Having explored on the link between conflict and resource scarcity in the previous sections, it is clear that resource scarcity acts in conjunction with a complex blend of economic, social, political and institutional factors (Fig.2), that eventually breed violence and determine adaptation capacity (Fig.2) (Martin, 2005; Kahl, 2006; Buhaug *et al.,* 2008; Krummenacher, 2008; Salehyan, 2008a; Bernauer *et al.,* 2011; Koubi *et al.,* 2012; UNIFTPA, 2012). These variables in concert with human actions undermine the availability of natural resources, bringing about scarcity and the resultant struggle for the existing ones (conflict) (Fig.2).

Economic and social variables tend to have a much larger effect on conflict and overshadow the effects of the environmental variables (de Soysa, 2000). The Environmental Conflicts Project (ENCOP), found that resource use conflict manifest as political, social, economic, ethnic, religious or territorial conflicts, or conflicts over resources or national interests, or any other type of conflict (Baechler, 1998).

Governance factors influence the range of response options available to different groups; including migration, adaptation strategies, coping and survival strategies, or direct violent conflict (Fig.2) (Bernauer *et al.*, 2011). Adaptation requires response on multiple levels and appropriate interventions depend on the mix of drivers (UNIFTPA, 2012), thus, scarcity does not just cause conflict, but (1) the interaction of the other variables; if positive leads to proper adaptation and if negative leads to conflict and (2) the path which the society choses to follow can either lead to resilience or vulnerability (Fig.2).

4.1 *The model*

Crisis due to resource scarcity is a daily signature dotting the landscape of West Africa, impacting on human populations, their livelihoods and social connections across the wider West African region. To manage its impacts and reduce resource and social conflicts, we need to identify the interconnections that exist between society, resources and the resource scarcity in what we term the "resource use – conflict pathway model" (Fig.2). The notion of resource use derived conflict has its roots in neo-Malthusian notions of carrying capacity and the interface between human population and available resources. As population increases there will be a scramble for the available resources which deplete with time. The model showed that when a society depends on scarce natural resource, (land, water, forest, agriculture) for their livelihoods, incidence of climate change in conjunction with other anthropogenic variables (Fig.2), will impact on human welfare by creating scarcity. Separately or in combination with other factors resource scarcity can destabilize livelihoods, negatively affect ecosystems and undermine peace and development and where local and national institutions lack capacity to resolve that, violent conflict may occur. Referring to this multidimensional interactions DFID (2008) identified five types of assets that form the core of livelihood resources; financial, human, natural, physical, to social capital, and by recent extension political capital which constitute the actual building blocks for livelihoods and the underpinning principles of a poverty focused and livelihood-oriented development. The DFID vulnerability context of livelihoods refers to shocks, trends and seasonality with their potential impact on people's livelihoods, while Policies, Institutions and Processes on the other side comprise the context of the political and institutional factors and forces in government and the private and the civil sectors that affect livelihoods. Depending on the magnitude and direction (+, -) of each of the intervening variables (socio-economic interactions) and the 'transmission pathway', a society achieves peaceful and harmonious coexistence or is ridden with conflict. For example, Collier (2000) found out that a country with large natural resources, many young men and little education is very much more at risk of conflict than one with opposite characteristics, even a slight increase in the level of education can decrease the risk of conflict. Findings also show that the higher the per capita income of the society the lower the risk of conflict (Human Security Report Project, 2007). This is the case in the West African Sahara area (e.g. northern Nigeria), where there is high amount of young illiterate population. The reverse is the case in southern Nigeria where there is a very high level of youth education.

4.1.1 Operationalizing the model.

This model, unlike the other conflict models in literature (e.g Bathos and Wehr, 2002; Bernauer *et al*., 2011) is unique; more elaborate, robust and operationalizes the linkages among the natural resource - socioeconomic variables and traced their pathways to conflict. Most importantly it x-rays the intra relationships among the actors and what possible outcomes that are expected, and when nipped in the bud does not result in 'poverty' which is the fertile ground for conflict. This is because, the primary cause of conflict is the feeling of deprivation and the quest to make both ends meet at all cost, thus the saying that 'a hungry man is an angry man'. For instance, the advent of climate change (Cc) acts on natural resource base (Re) (agriculture, forestry, water) (see fig 2), to render them unproductive and / infertile or they are over exploited and degraded and the people have no other source of livelihood, poverty sets in. If they have good adaptive capacity (e.g ability to diversify, personal traits) or receive external interventions (from donor agencies and the government as in the case of food aids, help from friends and relatives), then they are better able to adapt and are resilient. Individuals are better able to adapt when they have alternative livelihood options which guarantees their survival. Alternatively, if the individuals struggle with others in the same environment, or migrate to other regions, there will be fierce resistance from the settled communities, *potentially* leading to violent conflicts. This is the major cause of conflict between nomads and farmers across West Africa. While the former pathway results to building resilient societies, the latter perpetually leaves the individuals vulnerable to conflict due to successive displacement of settled communities (Fig.2). In the same vain, the interactions between socio-economic variables (Sc) and natural resources base (Re) results in ownership tussles; who controls the resource. This is the source of most conflicts all over the world. Socio economic variables (Sc) interact with economic concerns (Es) to mis-inform the people about who is responsible for their woes and thus are used by the elites to their peril in the struggle for economic and political powers. Also climate change (Cc) acts to undermine the economic base (Es) of the people in various ramification to create a state of deprivation, hunger and unemployment. In each case the endpoint is poverty and the vicious cycle continues to either breed conflict or build resilient when the right things are done.

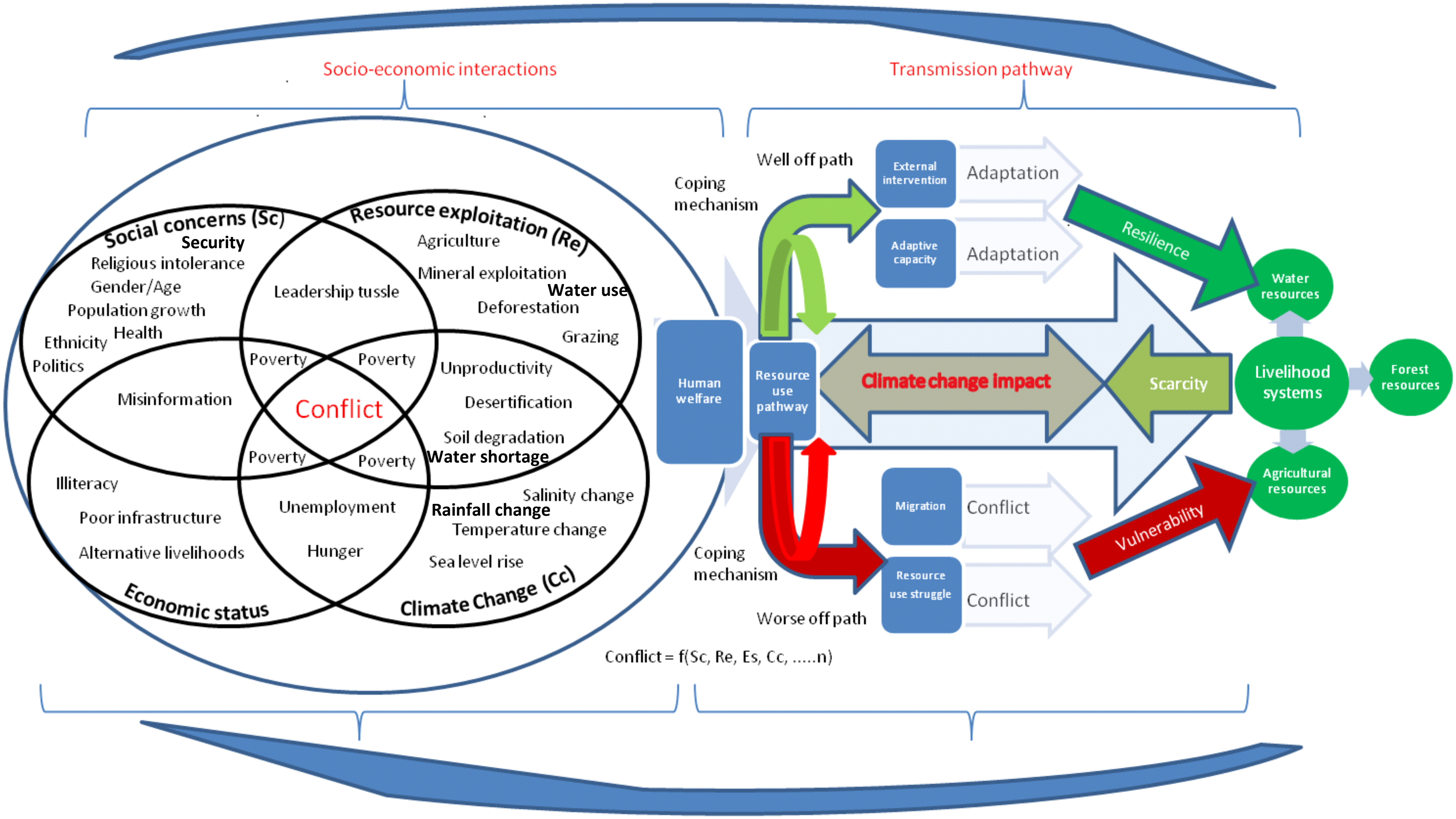

Figure 2. Resource use – climate change - conflict pathway model

> In figure 2, Sc ∩ Re focuses on the struggle for governance and resource control: this is most important in conflict management as different political, religious and ethnic groups engage each other in the struggle for control. Sc ∩ Es is the socioeconomic dimension of conflict; the former has an overbearing influence on the latter, shaping the livelihoods of the masses with negative nuances and policies, thereby impoverishing the people. Re ∩ Cc concerns the complex biophysical interactions that results in environmental degradation and resource depletion resulting from unsustainable resource exploitation due to 'Sc' and the uncertainties introduced by the exogenous impact of Cc. Es ∩ Cc results from the inability of the people to cope with the impact of Cc due to poverty, lack of knowledge / coping strategy and poor infrastructure, thereby exacerbating an already vulnerable situation. Depending on the prevailing circumstance, the interactions either engender resilience if the individual(s) adopt effective adaptation options or are perpetually vulnerable if they do otherwise. In an ideal situation without climate change and scarcity the two part transmission mechanism (coping mechanisms) do not exist as resources flow uninterrupted through the resource use pathway to meet human welfare; in this case all the interacting variables (socio-economic interactions) are positive and there is no conflict. It is only when the required resources become scarce due either to climate change, anthropogenic causes or natural disaster that the need for the two pathways arises.

This analogy is in resonance with those of other conflict scholars. Obioha (2008) asserts that the eco violence theories perspective of conflict explains that conflict is generated by the scarcity of natural resources the product of total *population in the region* and *physical activity per capita*, and second, *the vulnerability of the ecosystem in that region to those particular activities*. A state of deprivation and marginalization results in people becoming highly vulnerable to shock and more ready to join armed groups (de Soysa *et al*., 1999). Thus, scarcity in itself does not cause conflict, but the ability of the people to cope with scarcity is what determines whether there will be conflict or not. For example, someone who is well off is less likely to be involved in violent conflict. In this respect, the provision of aid, and importantly some certainty that aid will arrive, can help reduce the need for people to use violence to provide for their needs (Gough, 2002; UNIFTPA, 2012).). In many developed countries, established and effective welfare systems perform this function, which in part explains why they experience relatively less frequent and intense violent conflicts than developing countries. Human insecurity may in turn lead to more conventional security problems, with an increased propensity for people to engage in violence to protect or develop alternative livelihood strategies. This is a cyclic phenomenon that can be remedied with interventions or adaptation, be it from outside agencies (NGOs, government, international organizations), internal (friends, social groups, family members, community), self-adaptation or a combination of several of these. The complex interaction factors in our model (Fig.2), necessitates individuals to develop resilience through effective adoption of adaptive practices in the system to prevent being perpetually vulnerable to violent confrontation.

5.0 Suggested ways forward

To develop an effective system for managing conflicts, we must first identify the economic, environmental, social and cultural threats experienced by vulnerable groups. Secondly, we need to understand the causes, characteristics and factors that fuel different conflicts, and how vulnerable households and communities have traditionally managed such conflicts; this information can be used to develop effective conflict management strategies. In doing this three different, but interrelated options are at the disposal of conflict management practitioners; (1) conflict prevention options, (2) conflict remediation options and (3) post conflict management options.

5.1 Conflict prevention

Policies aimed at reducing ethnic conflicts and communal clashes in West Africa, must necessarily first link to the restoration of degraded lands, reduction of livelihood vulnerability, promote alternatives and improve the availability and access to natural resources. This should be done in order to mitigate the drivers of migration and conflict and help secure development gains. In the case of our model, it means that stakeholders have to understand the interactions between the different variables and take steps to nip in the bud the negative outcomes of their interaction (degradation, leadership tussle, misinformation, unemployment and hunger) and making sure they are identified in time when they set in, in order to reduce poverty or the feeling of deprivation.

Provision of livelihood options to reduce relative and absolute deprivation so that people can live a pleasant life with their basic needs met is a sure way of reducing vulnerability. There is the need to target transforming key economic, social political and institutional factors that could lead to violent conflicts in the future. This view is also shared by UNIFTPA (2012) that reducing livelihood vulnerabilities and promoting alternatives, improving the quality and quantity of natural resources and strengthening Natural Resource Management (NRM) and participation is a sure way to reducing conflict.

Thus alternative solutions to trans-humance agriculture of the Fulanis across West Africa, through the development of intensive small area grazing on hay and silage, and the establishment of standard ranches and grazing lands in the different parts of the country can ensure continuous feed for their animals. International organizations need to assist West African Governments in providing alternative solutions to the long and short range trans-humance agriculture of the cattle Fulanis. Obioha (2008) suggests that the grazing belt policies of West African Governments need to be religiously implemented if the conflict situation between the herdsmen and the settled arable farmers is to be minimized by mapping out areas of grazing which the arable farmers are prohibited to crop. This policy programme *inter-alia* provides a framework within which the herdsmen and the arable farmers can coexist with one another.

Stemming the southly migration of the Sahara through intensification of afforestation projects as is being done in the Green Wall Sahara Project should be intensified, this is an important step towards stabilizing the Sudan and Sahel zone. By planting new trees could stabilize desert areas, wetlands and coastline vulnerable to desertification and floods, cut emissions, and even create jobs while boosting economic growth.

At this juncture, it is worthy of note that not all conflicts are destructive, some are actually beneficial (Bartos and Wehr, 2002), Bartos and Wehr (2002) opine that too often, managing, reducing and resolving conflicts has simply deferred or postponed needed changes in power relations. It is therefore important for societies to build into itself a tolerance for ‘healthy’ conflict, like the United States whose members are growing increasingly tolerant of disagreements and differences and learning how to live with them more creatively and productively regardless of their differences. According to Coser (1956), both attraction and repulsion between groups are essential for social integration and continuity and healthy conflict is a part of societies’ developmental process to stability.

5.2 Conflict remediation

Conflict remediation actions are those that address conflicts when they are already in place. This can be done by first identifying the root cause of conflict, which is important in designing the appropriate solution for the conflict. Acting on such causes will be a sure way of de-escalating the said conflict. Causes could be social, when individuals struggle for societal influence, ethnic domination, religious differences or political struggle. In this case creating an avenue for fair arbitration is important. Addressing equity and justice issues have always proved to be sure ways of addressing social conflicts. If they are due to economic concerns, the implementation of programmes and quick interventions which guarantees employment and livelihood options for the citizens should be explored. In developed economies the use of effective social security options are put in place to address economic conflicts. In this case individuals feel secures and cared for and have no need to worry for economic security. In the case the conflict arises due to the struggle for scarce resources, the establishment of good property right system. Delineating and policing resource use to avoid overexploitation and misuse is recommended. And where it is due to natural phenomenon like climate change or natural disaster, implementation of good adaptation mechanisms to cushion the effect of the menace is vital towards conflict de-escalation. In general, putting in place transparent and efficient governance systems cannot be over emphasized in the quest for conflict remediation. Others immediate approach are the provision of immediate relief materials, food and good incentives to stop conflict and dispute resolution to take early action to defuse both imminent threats and broader instability are good options in reducing or stopping conflict. This should be followed by sincere and unbiased actions to resolve the existing conflict.

Whatever the case may be the provision of prompt and adequate security to prevent or de-escalate conflict remains key to conflict management in any society, de-escalation should be followed by dialogue and mediation to build mutual trust. In this regard UNIFTPA, (2012) is of the opinion that direct conflict management can be by dialogue, systematic data collection and early warning systems, information sharing on the status of the disputed resource, joint assessment organized by impartial, independent third parties that are acceptable to both sides, joint management plans, legal binding agreements and practical dispute resolution support. The approach of integrative bargaining should be adopted, which permits each party to discover common and divergent interests, which are met collaboratively through joint brainstorming and creation of new options (Bartos and Wehr, 2002). It is important that one should be clear about what is required to be done by the factions and how it can be made more likely that the things will be done in order to bring about the desired future. And agreement reached should be made operational by putting adequate mechanism for its implementation.

5.3 Post conflict management

The primary aim of conflict resolution should be to sustain the peace and prevent future occurrence. This can be done by implementing enduring policies and programmes that are targeted at addressing the root causes of conflicts and providing supports to those affected by conflict, especially women, children and the disabled. When conflict cases are resolved, there is the tendency for a breakdown of law and order if the issues that caused the conflict in the first instance are not addressed. Stakeholders should carry out research on the said conflict by engaging the stakeholders in the conflict objectively using independent assessors who are not biased about the conflict in order to fashion out a strategy for lasting solution. Agreements should be reached through give-and-take negotiations and instituting binding realistic treaties and measures (incentives) to enforce them. There should be constant supervision and monitoring of the situation to ensure all is working according to plan.

Some of these strategies that can ensure long lasting peace in conflict situations are promoting and protecting rights of local people to natural resource, fostering their greater participation in decision making, promote policies which encourage equality and inclusion. Design programmes which make governments more responsive and accountable to poor and excluded groups, improving access to justice for poor and excluded people, protecting the right of women and the less privileged in the society. The likelihood of violent conflict can also be reduced if we strengthen ways of managing disputes between individuals and groups fairly and speedily. This can be done by using local self-help organizations; castes, age grades, religious bodies, traditional rulers, local opinion leaders and chiefs, masquerade cults.

It is also possible to achieve conflict resolution by promoting mutual trust and cooperation in resource use, access and management. For example, in the case of Nigeria, Nyong (2007) advocate for the adoption of the Hadejia-Nguru Wetland Conservation Project strategy in resolving crop farmers – pastoralists' conflicts in the area. Realizing that a major source of this conflict was the lack of access to fodder for livestock the project promoted the cultivation of fodder by the farmers to sell to the pastoralists at a subsidized rate. Such a strategy should be modified and replicated in similar conflict situations**.**

Finally, the emerging strategies in the management of West Africa's violent conflicts have a strong foundation in African traditional cultures. Contrary to general belief in western paradigms, every African community has capacities for promoting mutual understanding and peaceful coexistence (Lauer, 2007). This is true of many pre-colonial African societies that used various indigenous knowledge and institutions to advance harmonious co-existence in the society, such social assets should be harnessed and modified o suit present day realities. Uncritical adoption of Western approaches to conflict management has adversely affected the stability and development of many African societies. Traditional strategies largely conform to the principles of compromise and collaboration and emphasis is placed on internalized values such as traditional oaths, rewards, vigilantes, informal settlements, checks and balances, decentralization, effective communication, good governance, honesty, openness, empathy, community solidarity, and individual loyalty to the group which promote greater feeling of belongedness and mutual trusts among groups. In as much as the western conflict management approaches have their strength in being more systematic and institutionalized, their integration with the rich African approaches that is based on core human values and care for individuals and community will be a good model for the present day conflict management approach. We therefore need to go back to the basics and see how best we can integrate our traditional conflict management strategies in modern conflict management processes and programmes. This can be done by harnessing these positive aspects of each approach into a single framework, thereby producing a model with which our conflict management practitioners are trained and principles for conflict management established.

6.0 Conclusion

Resource scarcity and conflict have been part of human existence; the link between the two no doubt has been documented by the famous work of Malthus and contemporarily by those of Neo-Malthusianism. The paper established that most cases of violent conflicts in West Africa are traceable to the struggle for the control of dwindling and degraded natural resource base of the region, which breeds poverty and scarcity in the already socially and economically fragile situations. Based on these linkages a conflict pathway model was developed with comparative advantages other existing conflict models for its robustness.

It is noted that most measures used in resolving crisis situations in West Africa treat the effects of resource scarcity without addressing the root issue of land modification, unsustainable farming and deforestation. The violence in the Middle-belt of Nigeria, for example, which has taken the lives of thousands of people, rendered many refugees and destroyed properties worth billions of Naira, does not have ethnic or political origin; the root is in resource scarcity and the struggle for possession. The paper suggests that socio-ecological crisis can be greatly reduced by implementing policies that address the root causes of conflict – poverty, addressing injustice and equity, improving and restoring degraded rural lands, provision of alternative means of livelihoods for the poor, education, employment, social security, making available basic infrastructure such as electricity, roads, piped water and processing of agricultural products, coupled with effective government policies and political processes. Most importantly reconnecting with the rich African social system of conflict resolution, by harnessing those indigenous knowledge and institutions into the reality of present day conflict management. These conditions will help to reduce the feeling of insecurity and address the root causes of conflict in the Nigeria, the entire West African sub region and other natural resource dependent systems.

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CHAPTER THREE

Climate change and forest resource use in Nigeria

3.1 Preface

Natural forests are thought to contribute directly to the survival of several millions of the world's poorest tribal people (Poffenberger *et al*, 1996). In a study of forest dependent people, DFID (2000) estimated that there are 12 million 'indigenous forest peoples' belonging to some 1,400 ethnic groups in the seven countries (including Nigeria) that are dependent on forest resources. In the study, dependency constitute those that use the forest as a source of water, fuelwood, shelter, medicinal plants and culinary herbs, nutritionally important forest fruits and other foods, timber, fodder, dry-season grazing and the broad suite of non-timber forest products (NTFPs) (bamboos, rattans, gums, resins, latex, oils). Going by this definition of dependence, virtually every Nigerian is forest dependent, as there is no one in Nigeria that does not use one or several of those products directly or indirectly. The forest foods are in the form of vegetables, fruits, nuts, tubers, seeds, oils, mushrooms, spices and drinks (alcoholic and non-alcoholic). Indigenous population in Nigeria have benefited historically from natural ecosystems through the use of NTFPs. Although NTFPs typically lie outside of statistics on official commerce, they provide a wide range of raw materials and inputs for a diverse array of rural enterprise. While some plants are off-season others are in season thereby giving security to the rural communities that depend on them for sustenance. For many developing countries like Nigeria, therefore, Bann (1997) asserts that forests represent an important resources base for economic development. If managed wisely, the forest has the capacity to provide a perpetual stream of income and provide subsistence products, while supporting other economic activities through its role in regulatory ecological services and functions.

The impact of global climate change will therefore have consequence for the livelihoods of those who depend on the forest for their daily survival. It is this dependence and the implication of climate change impact that are explored in this chapter. The chapter presents the social perspectives of how people are experiencing climate change impacts, perceived causes of changes in conjunction with adaptation pathways for resilience building among forest communities in Nigeria. Particularly key is the differentiation across agro ecological zones and the presentation of the questionnaire that underpin the rest of the thesis. These are presented in a paper titled; 'Climate change impacts and adaptation pathways for forest dependent livelihood systems in Nigeria**'** that has been published in the African Journal of Agricultural Research**.**

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3.2 Climate Change Impacts and Adaptation Pathways for Forest Dependent Livelihood Systems in Nigeria

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Abstract:
Climate change is projected to adversely impact rural livelihoods; especially forest communities dependent on climate sensitive natural resources. Communities living within five ecological regions (mangrove, rainforest, Guinea Savanna, Sudan savanna and montane forest) in Nigeria were assessed using structured questionnaires to gauge the impact of climate change and adaption responses. Households in the mangrove, rainforest, montane forest, Guinea Savanna and Sudan savanna derive 47%, 34%, 31%, 19% and 14% of their livelihood from the forest respectively. More than 75% of households surveyed have experienced impacts of climate change on forest resources, except in the montane forest zone where only 33% were impacted. In the mangrove and rainforest regions impacts were mostly manifest as excessive rainfall, in the montane forest, Sudan and Guinea Savanna, impacts were due to reduced rainfall. Adaptation options in the mangrove and rainforest regions were mainly used for forest conservation and to reduce the impact of excessive rains, while in the montane forest, Guinea and Sudan savannas most strategies are aimed to reduce the impact of aridity, such as irrigation, mulching, planting deep and the use of shades. Such community based information can provide a foundation to build an organized, systematic and mitigated approach needed for community-centered adaptive mechanism for sustainable forest resource management. Crucially this can be used to ensure a steady flow of livelihood support services from a range of ecological regions in Nigeria and across the wider West African sub region.

Keywords: Ecosystem, Forest Management, Forest Resources, Poverty, Sustainability

1.0 Introduction

One of the greatest challenges to livelihoods in the 21st century, particularly in developing countries, is the threat from climate change (UNDP, 2010) that could potentially reverse decades of development gains, such as those focused on achieving the Millennium Development Goals. Africa will bear the major import of climate change due to high population growth, reliance on rain fed agriculture, rapid development trajectories, high levels of poverty and low level of infrastructure.

In recent years there has been noticeable increase in average temperature of the earth. This is associated with climate change. Climate change is a large-scale, long-term shift in the planet's weather patterns or average temperatures (Met Office, 2014). As a result annual average temperatures are projected to increase between 1.8 and 4.8°C and annual precipitation will change by between –12 and +25 % (seasonal changes range from –43 to +38 %) in Sub-Saharan Africa by 2100 (Muller, 2009). Such a climate shift will impact on ecosystem composition (like the forest) and distribution with ensuing resource scarcity (UNFCCC, 2007), leading to ramified socioeconomic effects on those who depend on such resources for their livelihoods.

Forest dependent people are defined by DFID (2000) as those that use forest as a source of water, fuelwood, shelter and a broad suite of non-timber forest products (medicinal plants, culinary herbs, fodder, rattans, gums, resins, latex and oils). Virtually everybody in the West African region is forest dependent at different scales directly or indirectly on a daily basis. Such common pool resources can contribute substantially to livelihoods, particularly of the rural poor (Jodha, 1995; Cavendish, 1999; Kerapeletswe and Lovett, 2001).

Resources derived from forested areas are key components of the natural resource base and fundamental to the socio-economic well-being of any community, region or country (Bann, 1997; Inonio, 2009). This is particularly so in sub-Saharan Africa where most countries have large rural populations that depend directly, or indirectly on natural resources and agricultural activities for their livelihoods (Ezeani, 1995). With sustainable management, forests have the capacity to provide a perpetual stream of income and subsistence products, while supporting other economic activities through broader regulatory ecological services and functions (Neumann and Hirsch, 2000; Verweij *et al*., 2009; Watson and Albon, 2011). The contribution of forests to sustainable livelihoods cannot be over-emphasized; it is estimated that about 500 million people across the world depend on forest resources for their livelihoods (Roper and Roberts, 1999). Forests provide households with income, fuelwood, food security, reducing vulnerability to shocks and adversities and generally increasing wellbeing (Arnold, 1998; Warner, 2000; Fisher and Shively, 2005; Eva and Fred, 2013). More broadly, forests are vital for ecosystem and regulatory services, such as water and carbon management (Watson and Albon, 2011). Forest products add important variety, vitamins and increase palatability to main food staples (FAO, 2005). Food products such as roots, tubers, rhizomes and nuts are widely used between meals; eaten while working in fields or herding. In addition to these supplementary roles, forest foods are extensively used to meet dietary shortfalls bridging "hunger periods", when stored food supplies are dwindling and the next harvest is not available (FAO, 2005). Hence, forest products smooth seasonal peaks and troughs in farm production; a role that is particularly important in periods of floods, droughts, famines and wars. In Nigeria, for example, over 90% of the rural population depends on agro foresting for livelihoods (Federal Government of Nigeria, 1997; UN, 2002; IMF, 2005; FAO, 2008), deriving over 10% of the Gross Domestic Product from the forest sector (FAO, 2003), thus, underscoring the importance of the forest sector to the socio economic lives of the Nigerians.

Against this backdrop DFID (2009) asserts that climate change could result in between 2 to 11% GDP loss globally by 2020 and from 6% to 30% by 2050; costing an estimated US$ 100 to 460 billion. Given the importance of forest resources, it is paradoxical, that in spite of their current and potential value, how individual respond to climate change is relatively under-researched (Aiyeloja and Ajewole, 2006).

Context of the paper

This paper aims at quantifying forest dependence and assessing the impact of climate change on forest resources and captures the ensuing adaptation options adopted by the households to cope with the impacts of climate change in managing their forests resources. Although the study is in Nigeria, results are applicable to the wider West African region due to comparable vegetation and communities.

2.0 Materials and methods

The data for the study was collected with the questionnaires. The questionnaire evolved through various stages of development. It passed through several writing, editing and correction between the researcher and the supervisor with inputs from the Technical Advisory Committee (TAC) members for the research. Finally it went to the ethics committee for final approval. Elements covered in the questionnaire were issues on the personal characteristics of the household (head), their agro – forestry activities, types of forest, forest governance, access to forest, forest management, forest resource use and dependence, climate change perceptions and awareness, forms of climate change impacts (Appendix 1) and adaptation strategies adopted by the households (Appendix 2), costs and benefits of adaptation and constrains to adaptation. In Nigeria, the research team was brought together considering their level of education and experience in such social research, their knowledge of the local languages in the selected communities and their availability for the duration of the study. They were practically trained by the researcher on the different components of the questionnaire and the overall expectation of the research. In order to trial the questionnaire a pilot was conducted with few questionnaires to validate the actually interviews and address issues and areas of concern. After the pilot some of the questions were found to be ambiguous, while the respondents were reluctant to answer some, so they were rephrased properly**.** Through a house to house visit of the randomly selected households by the research team in five different ecological regions of Nigeria (Fig. 1) in three months over 400 interviews of the household heads were made and documented in the questionnaire.

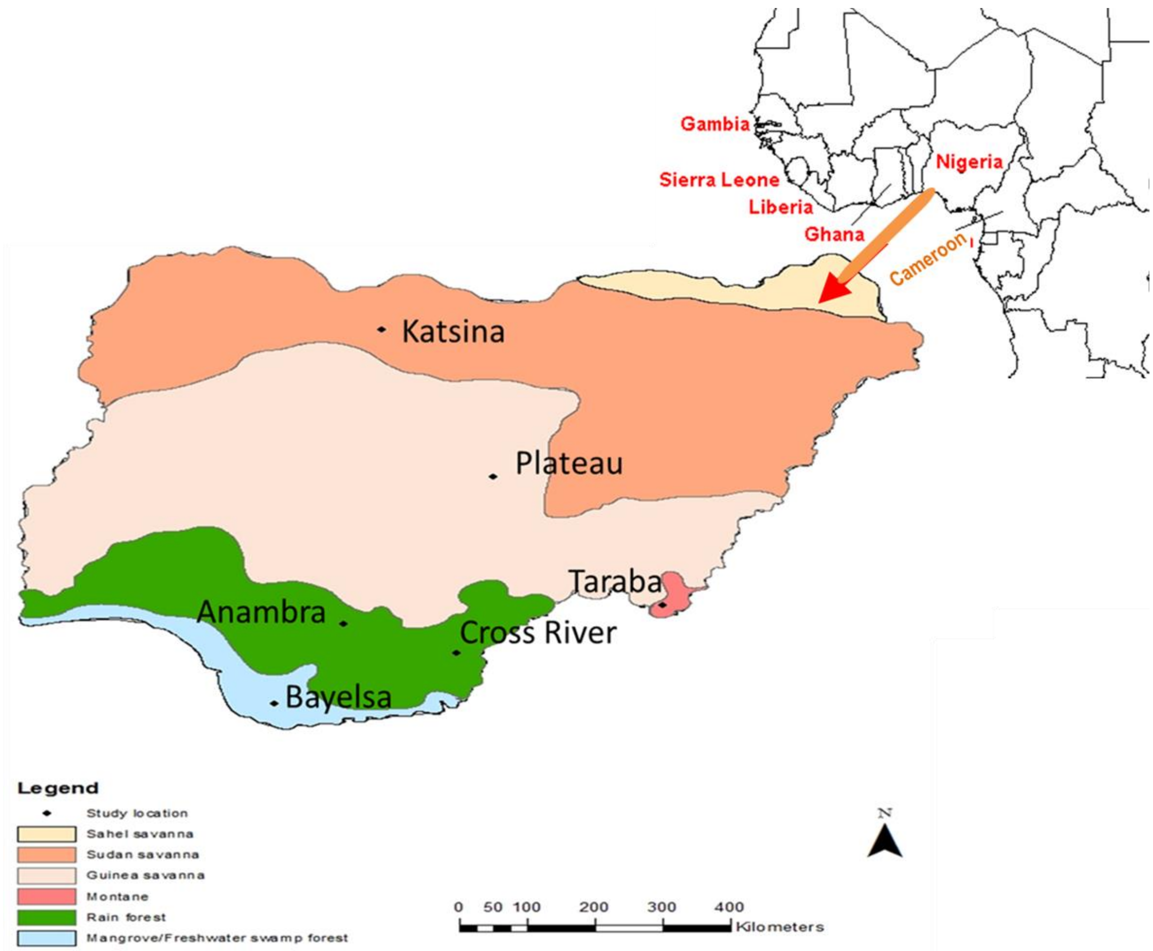

Figure 1: Map of Nigeria; showing areas where the study was carried out

Based on the relative size of the population which they support, and the prevalence of forest cover, 150, 100, 100, 50 and 50 households were sampled from the rainforest, mangrove forest, Guinea Savanna, montane forest and Sudan savanna zones respectively. For the rainforest zone the Cross River high forest was chosen as this is the only area of surviving lowland rainforest cover, not just in Nigeria, but across West Africa. Communities were selected from the respective states and research assistants in each of the area who understood the local languages were used for the study. Communities were selected based on information from local informants on their reliance on forest resources. Five communities were selected from each of the rainforest and mangrove forest areas, four from Guinea Savanna (Appendix 3), three from montane and two communities were chosen from Sudan savanna ecozone. Communities were chosen using a random draw from all possible communities in the target areas. In each community households were randomly selected using the communities' roll calls. From the roll call, different households were selected at random intervals until the required number (150, 100, 100, 50 and 50) of households per community was reached (this was directly proportional to the total population of the different communities). Structured questionnaires were administered on a one to one basis, with the household heads, or other family members who were familiar with forest resource use by the household and the wider community. To check for interviewer bias and ensure data consistency and compatibility, the addresses and mobile phone numbers of each respondent were collected and information supplied by the interviewer randomly crosschecked in all zones. The data collected were coded and screened for consistency and analyzed using STATA statistical software.

3.0 Results

Results are presented in three sections; the first section presents an overview of how forest resources contribute to household livelihoods. The second section assesses how communities perceive climate change impact in their use of forest resources. The third section focuses on the different adaptation options adopted by the households in the face of such climate change impacts across Nigeria.

3.1 Forest contributions to livelihood system

Forest resources are important to the livelihoods of the households across Nigeria (Fig. 2). Forest resources in the mangrove ecosystem contribute an average of 47% to household income with a range of 10–80%; households depend on both aquatic and terrestrial flora and fauna for food and income. Rainforest communities derive an average of 34% of their livelihoods from the forest with a range of 10–95%. Montane forest contributes an average of 31% to livelihoods with a range of 5–95%. Guinea Savanna contributes about 19% with a range of 5–80% (although with a big skew to low dependence), while the Sudan savanna contributes the least; 14%, with a range of 5–30%. On average, forest resources supply about 39% to the livelihoods of rural populations in Nigeria.

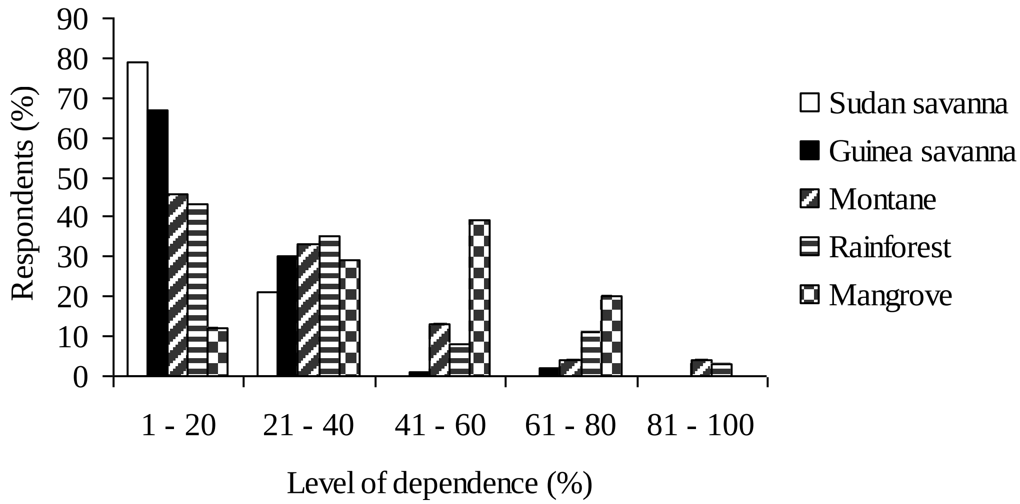

Figure 2: Level of forest dependence across ecological regions in Nigeria

3.2 Changes in forest resource use and their drivers

Most respondents across ecological zones have experienced changes in their use of the forest resource (Table 1). Perceptions of climate change, and how these impact through forest resource availability and use in the different ecological zones, were determined (Fig. 3), and the general consensus was that that, climate change is predominantly responsible for the changes (Fig. 4).

Table 1: Towns used for the study in each ecological zone

Ecological zone	State	Town
Mangrove	Bayelsa	Koroama, Okolobiri, Obuna, Polaku and Nedugo
Rainforest (Dense)	Cross River	Nsak, Okuni and Urban
Rainforest (Sparse)	Anambra	Isi Achina and Umuchu
Guinea Savanna	Plateau	Riyom, Mangu, Kanke
Montane	Taraba	Garin dogo Zau. Lushi garin dogo zau, Gang Bentsa-Dakka and Gani-Dogo Lau
Sudan Savanna	Katsina	Daddara and Jibia

In the mangrove ecosystem some of the key impacts are increased weed infestation, floods and erosion and increasingly erratic rainfall patterns. In the rainforest ecosystem the most serious impacts are floods and erosion, heavy and long periods of rainfall, high temperature, uncertainties in the onset of farming season, increased disease incidence and weed infestation. In the montane ecosystem impacts are characterized by delayed onset of rain, reduced harmattan, less rainfall, higher temperature and erratic seasons. In the Guinea Savanna ecosystem the major climate change impacts are a delay in the onset of rainfall, increase in pests and weed infestation, drought, erratic rainfall and higher temperatures. In the Sudan savanna the most important impacts of climate change are reduced rainfall, drying up of streams/river, delayed onset of rain, uncertainty in the onset of farming season and increased incidence of wind (Fig. 3).

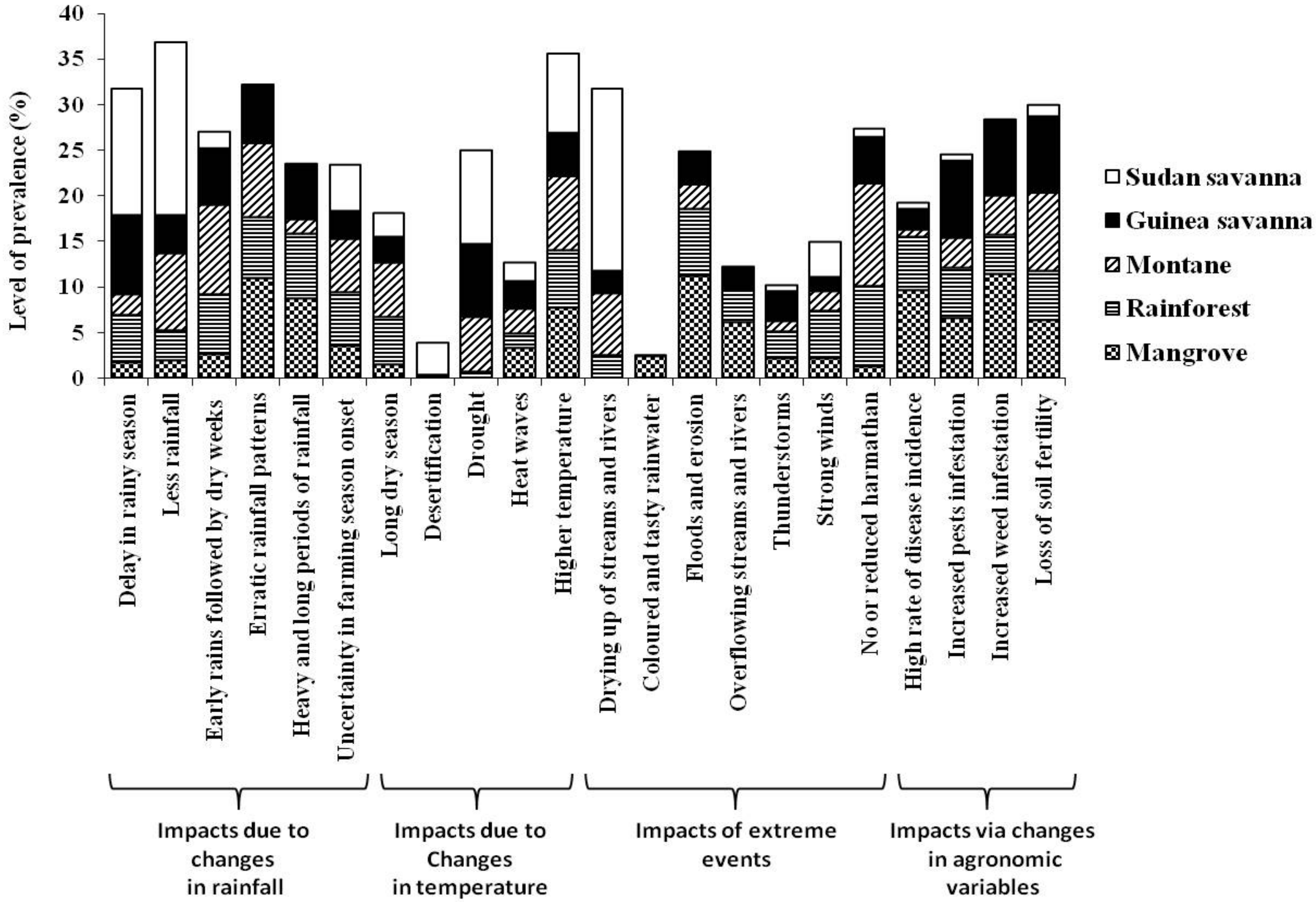

Figure 3: Climate change impacts in the different ecological regions

There was a consensus among households that climate change was responsible for the changes in forest resource use across all the ecological zones (Fig. 4). Other drivers of changes in forest resource use result from increased population, development, over-exploitation, shifting cultivation and increased use of fertilizer. Gas flaring was identified as a major driver of change in the mangrove region. Overgrazing was a prominent impact in the montane and savanna areas, in the latter area loss of soil fertility was identified as influencing changes in forest resource availability and use. Logging was a predominant concern in the mangrove, rainforest and montane forest areas.

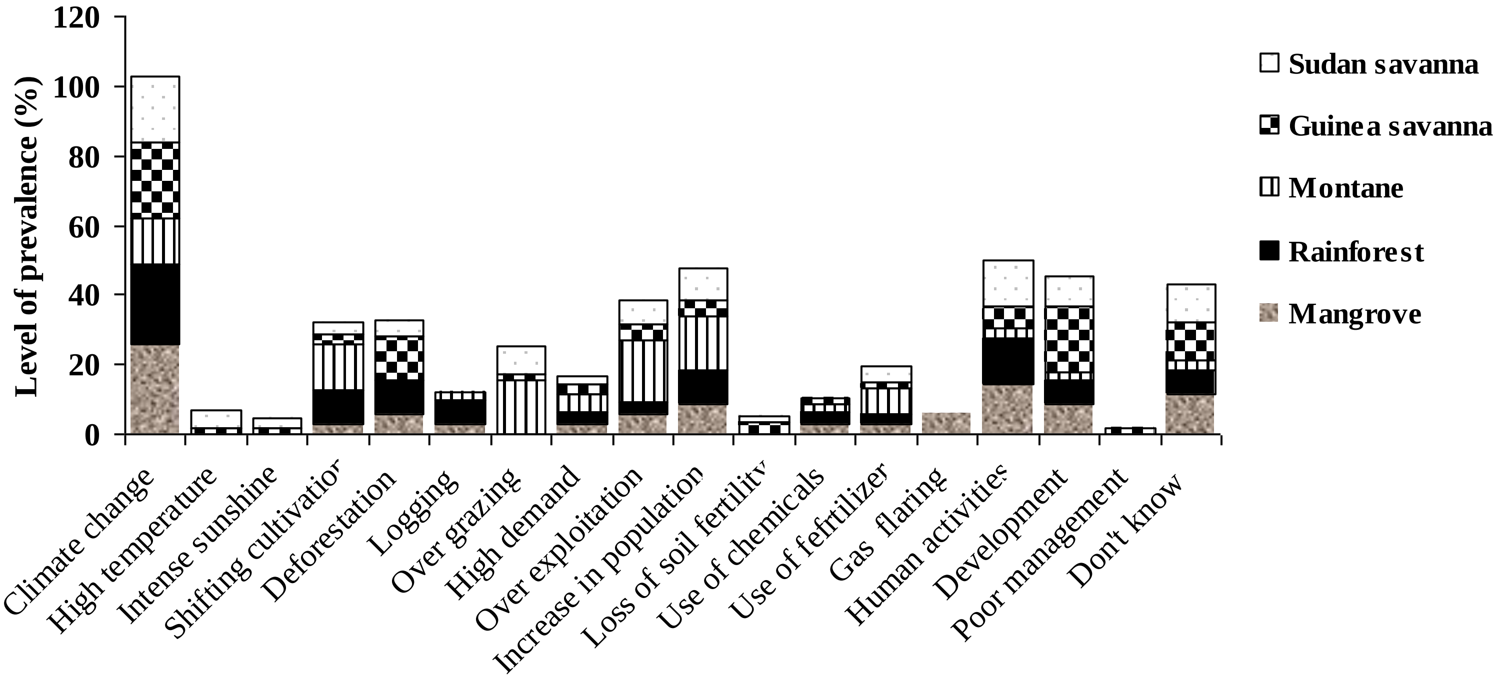

Figure 4: Causes of changes in forest resource use

3.3 Adaptation options used by the households to mitigate climate change impacts

Households were asked about any adaptation options, over and above their usual agronomic practices, being used specifically to mitigate climate change impacts. The most common response across all the ecological zones is agroforestry, being practiced by 20%, 33%, 36% and 27% of households in the mangrove, rainforest, montane and Guinea Savanna zones respectively (Fig. 5). Other options include increased weeding, mulching, plant replacement, and building of shades for plants (especially for young trees). Irrigation is the predominant response in the Sudan savanna. Water shade management is prevalent in the mangrove, rainforest and montane forests. Changing the timing of farming activities, such as increasing the fallow period and avoiding burning, is widely practiced except in the mangrove ecosystem. The use of energy saving cook stoves and use of local drip irrigation are increasingly used in both the rainforest and the montane forest areas. Increased spraying and selective tree cutting are used in the rainforest, montane and the Guinea Savanna, while an increasing use of wetland areas is predominant in the mangrove ecosystem.

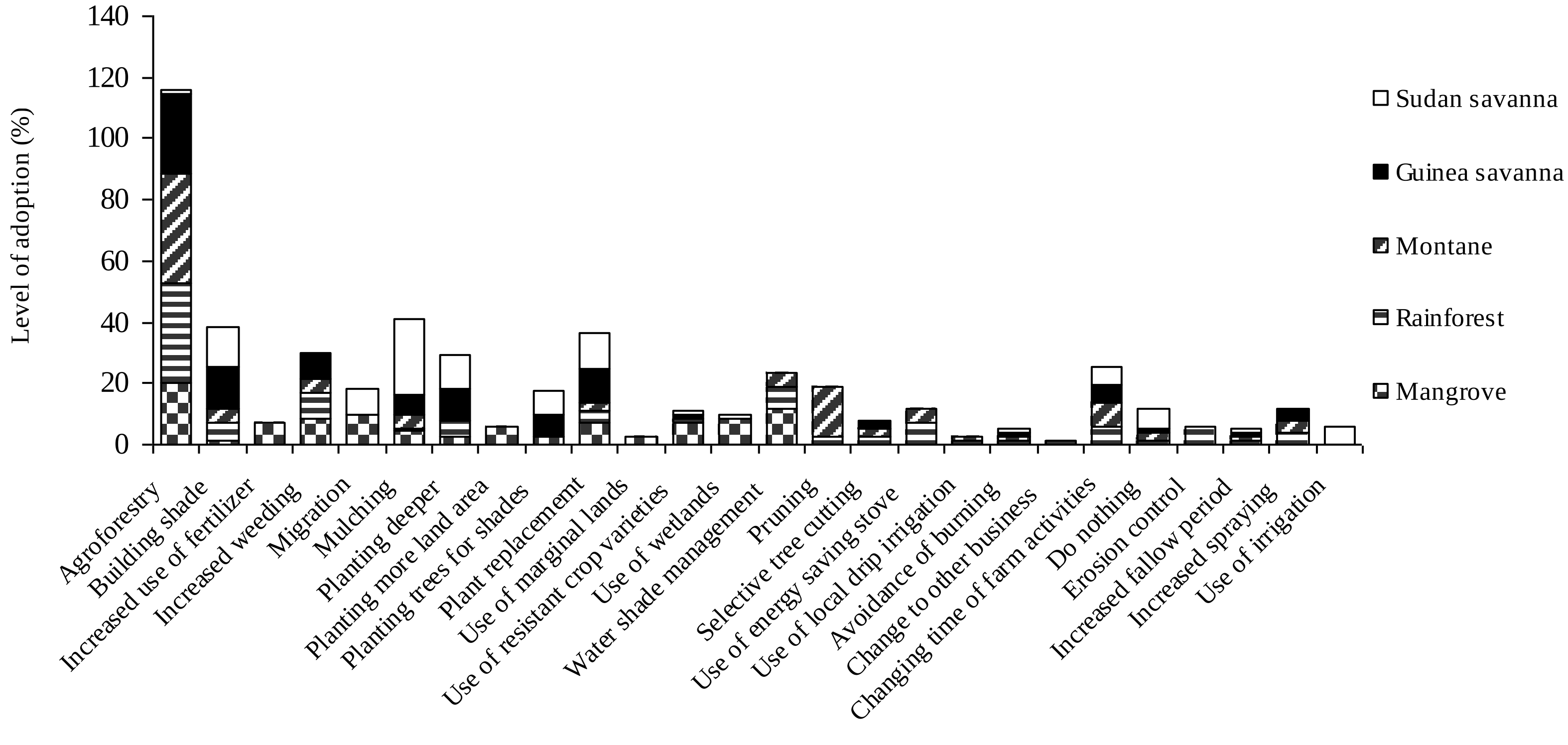

Figure 5: Adaptive forest resource management practices in response to climate change

4.0 Discussion

The discussion will be focused around three key issues; the dependence of communities on forest resources to support livelihoods, how climate change impacts on this and what forest resource management strategies are being implemented to adapt to climate change. How insight from these two areas can be used to develop more effective forest management strategies for Nigerian communities, and the wider West African region, is discussed.

4.1 Level of forest dependence in West Africa

Indeed, the results clearly show a high level of dependence on forest resources by rural households, particularly in the mangrove and rainforest ecosystems, gradually declining towards the Sudan savanna. This is because these regions are the parts of the country with the largest concentration of dense mangrove and rainforest with abundant specie richness compared to the other regions that are grasslands. These results corroborate the study by Inonio (2009) that found income from forest resources account for 67% of the total income of the lower income group and some 41% of the highest income group in rural households in Delta state Nigeria. The average annual value of harvested wild plant products from the Nigerian forests per household was 1,614,133 Naira (US$11,956); the annual net income generated from the harvest of wild plant products per household was 910,252 Naira (US$6,742) (Osemeobo, 2005).

Furthermore, the findings also resonate with those of other scholars who identified non-timber forest products (NTFPs) to account for an enormous share of household income (Liedholu and Mead, 1993). Also in southeastern Nigeria alone, 36% of the rural population collected NTFPs daily, accounting for 94% of total income in 1996 (Nweze and Igbokwe, 2000). Wild plant products support a number of occupations in Nigeria; the most profitable being vegetable oil, chewing stick, soap, wine, fuel wood and charcoal production (Osemeobo, 2005). Apart from the provision of food and income, NTFPs are also used for traditional medicines, divination, masquerades, religious ceremonies and the production of musical instruments (Osemeobo, 1993). There has been a recent and noticeable shift in many African countries and indeed worldwide, from orthodox ‘western’ medicine to greater use of traditional (herbal) medicines (Akunyili, 2003). Over 90% of Nigerians in rural areas, and 40% in urban areas, depend partly or wholly on traditional medicine (Osemeobo and Ujor, 1999; Bisong and Ajake, 2001). It is therefore not understandable that in spite of their real and potential value, most NTFPs remain grouped as minor forest products; these products rarely feature in statistics of forest use (Aiyeloja and Ajewole, 2006).

Aside from the direct contribution to food and economic wellbeing, there are so much intangible benefits that are closely tied to the social livelihood of the rural people. Rural communities, and to a great extent forest dwellers, have a cultural and religious bond to the forest. Knudston and Suzuki (1992) have explored the protective function of culture within a comparative perspective. Others note that for millennia humanity has had a social and cultural basis for protecting nature (Sousson *et al.*, 1995). Indigenous belief systems have a major protective role in a culture's relationships with the natural world, and in nature's relationship with a culture. Traditional community activities include ceremonies and festivals which utilize NTFP like skins of antelopes, crocodiles, monitor lizards and photon for drums and other musical instruments, kola (*Cola accuminata, C. nitida* and *Garcinia cola)* for sacrifice and prayers, palm wine for traditional ceremonies, festivals and relaxation.

Although our questions focused on the specifics of forest use, the broader ecosystem services and functions provided by forests cover a wide range of ecological, economic, social and cultural considerations and processes (Lindberg, 1997). Forests also provide scenic and landscape services and values, this more general set of services highlights ideas of aesthetics and beauty as components of forests. Trees play a fundamental role in biogeochemical cycles, improve soil fertility, control erosions, provide shelter belts, fix dune, rehabilitate eroded terrain and provided a 'land bank' that can underpin sustainable livelihoods (Oriola, 2009; Pataki, *et al.,* 2011).

4.2 Climate change impact on livelihoods

Against the backdrop of forest product use dependence, people are highly vulnerable to the impacts of climate change. This is because it acts on the very soul of their sources of livelihoods, upon which they depend on daily basis for their sustenance. In this regard, there was a consensus across all regions that changes in forest resource availability and use was in part resulting from climate change (Fig. 4). Directly, the impact is influencing the biophysical environment, especially water availability and temperature regimes that are interacting to reduce agricultural production and forest resource availability. The impact can be quite extreme and as it was the case in the adaptation practices in the mangrove and Sudan savanna areas ultimately lead to the migration of people from areas of impact, such as associated with desertification and sea level rise, to areas of more marginal forest cover, leading to excessive exploitation and potential conflict (Onyekuru and Marchant, 2014b). Such an impact is exacerbated by the interaction of other socioeconomic factors, such as development, population growth, agriculture / deforestation, increased use of fertilizer and urbanization, which can act in concert with climate change to impact on forest resources. Ironically high temperature and sunshine (which are indicators of climate change) has been highlighted as distinct variables in the results because those are the concepts understandable to those respondents especially in northern Nigeria (Sudan and Guinea savannas as shown in figure 4), and also, it shows the contract from the other aspects of climate change, like excessive rainfall experience in southern Nigeria. Ordinarily one will expect that increased use of fertilizer should have a positive impact on forest resource use; yes that is true to an extent, increased use of fertilizer was identified as a cause of decline in forest resource use because the rural forest communities see fertilizer as ‘a chemical that kills the soil’; owing to their experiences over the years that lands where fertilizer has been used excessively were usually less productive relative to those in which it has not been used. This situation arises *inter alia* due to misuse of fertilizer over time or acidity of the soil due to fertilizer use, especially in the areas with high population density. Thus many prefer not to use fertilizer in their operations but turn to other natural methods of soil restoration like bush fallowing (Fig. 5).Although the nature and intensity of climate change impact vary from place to place, there is no doubt that its effect on peoples’ lives and welfare is enormous, and will only increase under current predictions of climate change, especially in Sub-Saharan Africa (Deressa, 2010).

The impacts of climate change (Table 1, Fig. 3 and appendix 1) vary spatially; in montane areas the impact is relatively low compared to other areas. This result may be attributable to the resilience of the montane ecosystem as a cooler habitat; this has also been identified by BNRCC (2011) in the Jos area of Nigeria. The relative resilience of the tropical montane forests to climate change and drought has also been documented by Nadkarni and Solano (2002) and Ching *et al*. (2011). The general impact trend is one of higher rainfall in the south to less rainfall and greater aridity towards the north of Nigeria (Fig. 4). This result is in line with physical assessments that project an increase in rainfall during the rainy season months in the south of Nigeria and a decrease in rainfall amount towards the Sahel savanna though the 21st century (AIACC, 2006; IPCC, 2007; Tompkins and Feudale, 2010). However, there remains high uncertainty about regional predictions in rainfall in West Africa (Willey, 2008; Buontempo, 2010). Existing rainfall forecast and general circulation models have some fundamental weaknesses when applied to West Africa and have difficulty simulating the annual cycle of rainfall (Redelsperger *et al.,* 2006). A comparison of the Sahelian climate observed (1961-1990) with climates simulated by six general circulation models show a marked rainy season almost throughout the year along with a considerable bias (140-215 mmyear^{-1}) in annual aggregate rainfall estimates as compared to the observed data (ECOWAS-SWAC/OECD, 2008). In some of the models, the start of the rainy season appears one to two months prior to the observed (Kamga and Buscarlet, 2006). Such discrepancy in different models on the impact of changing climate regimes further highlights the importance of capturing information on climate and ecosystem variability from other sources such as historical and earth observation data (Pfeifer *et al*.,

2012) or capturing societal perspectives and community memory as presented here. Though may not be perfect, peoples memory and perception are vital in understanding climatic anomalies, especially where their perceptions are in agreement with measured trends and consistent across space, which was the case in this study. More importantly the information is coming from rural based stakeholders who are closely connected to these resources and climate trends which impact on their livelihood on daily basis. Their views can therefore act as an arbiter where such disagreements exist between observed and simulated trends, since they are the ones that actually experience the impacts and are in a better position to tell the story.

4.3 Adaptive forest resource management strategies in the face of climate change

Among the adaptation options identified in this study agroforestry stood out as the adaptation option of choice for most of the farmers. In addition to providing shade, trees produce fruits and generate additional income. Agwu *et al.* (2011) also found out that 23% of the rural dwellers in Nigeria use agroforestry as an adaptation option to climate change. Kowero (2011) assert that local communities are using autonomous traditional knowledge and practices in their attempts to cope with current climate viability and change, as they have done throughout time. According to Larwanou *et al*. (2011), a number of studies have shown that African communities, particularly at the local level, have intimate understanding of surrounding forests and have historically developed coping strategies to adverse climatic conditions, such as using agroforestry systems, and are currently making efforts to adjust to environmental changes being experienced. In addition, Roberts (2009) suggests that the revival, further development and application of such indigenous knowledge and associated social institutions and governance structures represent an important element in the adaptation responses of forest-dependent people to climate change. Capturing and maximizing the potential of the traditional approaches and knowledge, combined with insights from forest science, will be critical for the development of effective strategies for coping with anticipated changes in forest productivity. In essence achieving a situation where the use and management of forests are both adapted to anticipated climatic conditions and valued by local communities (Sampson *et al.*, 2000; Parrotta, 2002; Kowero, 2011). The use of agroforestry as an adaptation option to climate change will no doubt continue to expand in all the zones, not just for the fact that it meets the livelihood needs of the farmers, but it is also a source of security to the farmers in times of crop failure, as the farmers will have an alternative income source, firewood, stakes and posssibly fruits. Enete *et al.* (2011) identified agroforestry as ranking second (after multiple/intercropping) in profitability of adaptation options and promotes shading and shelter, reduces further depletion of forests, increase food production and at the same time responds to process of rebuilding soil fertility (Okali, 2011).

Beyond the local gains of using agroforestry, this practice is recognized by many as a trailblazer in the quest for climate change mitigation for its ‘win–win’ advantage, combining local use (timber, fruit, shade, medicine,) with global issues of carbon sequestration (FAO, 2005; Kleine *et al.,* 2010; Kowero, 2011; Opere *et al*., 2011; Larwanou, 2011; Larwanou, *et al.,* 2011; Spence, 2005, Ranasinghe, 2004; UNFCCC 2008; Agobia, 1999). Agroforestry has a particular role to play in mitigation of atmospheric accumulation of greenhouse gases, due to potential for carbon sequestration, improve soil nutrient, nutrient uptake, water percolation, aeration, water recharge and general soil water balance, thus should be encouraged (Louise *et al.,* 2007; Prabhakar and Shaw, 2007; IPCC, 2000).

A special form of agroforestry identified in this study is watershed management, used to moderate water flow and protect streams from drying up. Farmers avoid cutting the forest and leave strips of about ten meters between their farms and the streams. A number of communities also practice similar watershed management practices in other countries (Kerr *et al*., 2002; Farrington and Lobo 1997; Turton and Bottrall 1997; White and Runge, 1995; Ravnborg and Guerrero 1999). Findings also show that drought-induced impacts in India have reduced the average crop income (as a percentage of total household income) in non-watershed managed farms from 44 to 12%, this share remained unchanged at about 36% in the adjoining watershed managed farms (Shiferaw *et al.,* 2005). Another form of watershed management is selective tree cutting which provides alternative shade for arable crops in Nigeria. In addition Nyong *et al.* (2007) reports that local farmers increase the fallow period of cultivation, which encourages the development of forests and mitigate moisture and nutrient deficiencies (Mertz, 2009; Skinner, 2002; Swearingen and Bencherifa, 2000) as a measure to address climate change-related impacts.

Mulching was also identified to be on the increase in all the zones. Mulching protects sown seeds by moderating soil temperatures, suppressing diseases and harmful pests, and conserving soil moisture (Nyong *et al.,* 2007; Salinger, 2005; Ishaya and Abaje**,** 2008). Agwu *et al.* (2011) also found out that 74% of Nigerian farmers use mulching as an adaptation to climate change. Schafer (1989) and Osunade (1994) also report the use of mulching in the Sahel to conserve carbon in soils and is becoming increasingly common with the rise of organic farming and potential for reducing GHG emissions (Nyong *et al.,* 2007).

Furthermore, increased time spent on weeding across the ecological zones, due to increased rainfall during the rainy season is common, particularly in the rainforest. Farms are weeded two or more times than usual; this resonates with the finding of Apata *et al*. (2009), Agwu *et al*, (2011); Enete *et al.* (2011) and Ozor *et al.* (2012) who found out that 64% of Nigerian farmers experience increased weeding as an impact of climate change.

Due to uncertainties in farming season, particularly increasingly erratic rainfall patterns, households change their time of farming activities to start planting whenever they are sure that the rains have stabilized. Agwu *et al*, (2011) found out that 38% of farmers in West Africa change their planting dates in response to changes in rainfall pattern due to climate change. Swearingen and Bencherifa (2000), Smit and Skinner (2002), Salinger (2005), Howden *et al*. (2007**),** Ishaya and Abaje (2008), Deressa *et al*. (2009), Apata *et al.* (2009) and Enete *et al*. (2011) also identified the change in the timing of farm operations in different parts of Africa.

Associated with changing of planting dates is the use of irrigation in order to cope with water shortages and / or plant in normal seasons when the rain has not come. Irrigation practices improve farm productivity and enable diversification of production in light of climate-related changes (Brklacich *et al.*, 1997; Klassen and Gilpen, 1998). Implementing irrigation practices involves the introduction or the enhancement of specific water management innovations including centre pivot irrigation, dormant season irrigation, drip irrigation, gravity irrigation, pipe irrigation and sprinkler irrigation (Smit, 1993). In the rainforest and montane regions, locally fabricated drip irrigation is practiced to supply water to newly transplanted seedlings to help establishment. It is a unique form of irrigation predominantly used among cocoa farmers in Cross River State Nigeria. After repeated years of crop failure due to drought, some farmers trialed a drip irrigation system using empty cans with small perforation at the base, wide enough for water to drip (approximately one drop in every 5 – 10 seconds) with the other end open, (in some cases, fine sand is poured into the base to regulate water flow), the cans are filled with water and with a stick each is tied just above the base of each plant, until the cocoa plants are well established. In this way most farmers have recorded up to 100% success in plant establishment, though it is predominant among farms close to the streams as this might not be cost effective elsewhere. Findings have also shown that a wide variety of local technologies have been developed in semi-arid and arid regions, to harvest and conserve water in traditional silvo-pastoral and agroforestry systems (Laureano 2005; Osman-Elasha *et al.*, 2006; Larwanou, 2011).

The increased use of wetland is prevalent in the mangrove ecosystem where farmers take advantage of areas periodically flooded by fresh water from streams to cultivate vegetables and flood tolerant crops. The resilience and increased use of such groundwater wetlands in the face of climate change has also been reported by Morton (2007); Deressa *et al.* (2009), Fernández (2010) and Murdiyarso *et al.* (2012). In general irrigation increases soil moisture in the light of moisture deficiencies associated with climate change and reduce the risk of income loss due to decreasing precipitation, increasing evaporation and recurring drought (Smit and Skinner, 2002).

Aside the different on-farm adaptation techniques, in the homes the households also one some adaptation options, which also saves them time and cost. One of such options is the use of improved wood-burning cook stoves (ICS) which has been developed since the mid-1970s. This option addresses the two main drawbacks of open fires, by including a combustion chamber and a tube to take the smoke outdoors (Troncoso, 2007). The use of ICS, especially in the rainforest and montane areas by the rural households is regarded as another 'win–win' option; as it is not just effective in climate change abatement (saving the forest by reducing the amount of fuelwood used for cooking), but very cost effective. The ICS is made from locally available materials (Fig. 6). During cooking, up to one quarter of the usual amount of firewood used in open fire stove are used, while retaining virtually all the heat directly below the pot and the smoke is channeled outside the wall through the hollow in the bamboo stick. Nangoma and Nangoma (2007) report that the ICS uses less firewood than an open fireplace, produces more heat energy, produces less smoke and runs on any form of available fuel. In places where this stove has been introduced in Nigeria, virtually all the households in the communities have adopted the ICS and found children have more time for their education and the women more time for profitable ventures like farming, trading, social activities which help improve their socioeconomic wellbeing. Also impacts on forest are reduced with potential higher carbon sequestration.

Since the burden of preparing the household meal lies on the women in most traditional homes in developing countries, the ICS saves them from being exposed to the physical challenges occasioned by the use of excessive wood in traditional wood burning open stove. In addition the smoke causes a lot of health impact, especially for the women and their children who they carry in their back while cooking. The association of adoption of climate change adaptation options, especially ICS with greater opportunity for social progress has also been reported by the World Health Organization in improving health (Akbar *et al.,* 2011) and Bennett (2013) with regard to other social benefits. A report by the WHO estimates that 4 million people, in particular women and children, die prematurely from smoke inhalation, respiratory illnesses or incur long-term physical harm from collecting fuel (WHO, 2014). Particularly, in Africa Bennett (2013) has noted that the use of ICS addresses most of the MDGS as follows: by reducing the required fuel by two-thirds, poverty is reduced and more money is available for other purposes (MDG 1). Less time needed for collecting fuel by women and children allows more time for other activities such as education (MDG 2 and 3), is physically less demanding and reduces the exposure of women to the risk of physical attack. The health and safety of mothers and children will also improve because of substantial lower smoke levels (MDG 4 and 5). Moreover, the cookstove ensures environmental sustainability, because of lower fuel consumption and reduced deforestation (MDG 7) (Bennett, 2013). These and other concerns clearly justify the need for urgent integration of ICS into the socioeconomic lives of rural households in the developing world.

Figure 6: Energy saving cook stove before the kitchen wall is covered

Bailis *et al.* (2009) report that dozens of organizations have developed projects to promote ICS since the mid-1990s; one of such was the Mexican Patsari Stove Project that was well suited to local cooking practices, burnt less wood by over 60% relative to traditional cook stoves (Bailis *et al.*, 2007; Masera *et al.,* 2007; Barnes *et al.,* 1994). Interventions for disseminating ICS since the 1970s were mainly designed for increasing fuel efficiency, often because of a link between deforestation and household energy use (Eckholm, 1975; Arnold *et al.,* 2003; Ruiz-Mercado, 2011). Thus, there are more than 160 cook stove programs running in the world, ranging in size, scope, type of stove disseminated, approach to technology design and dissemination and financial mechanisms. The two largest and longest programs are credited with introducing approximately 210 million stoves between them, 85 % in China and 15% in India, and affecting the lives of more than a billion people (Gifford, 2010). In the case of India, reducing deforestation was often the main motivation (Bailis, 2007). The Chinese program focused primarily on increasing fuel efficiency to sustain local welfare and stem the demand for fossil fuels in rural areas (Smith *et al.,* 1993). The foregoing therefore justifies the need for an institutional framework for a more robust integration of ICS in the livelihood system of not just the forest communities but across the country. In the light of the foregoing, regardless of how beneficial these energy use option could be in the short run, what their long time implication can be is yet unclear. This is because of the fear among certain scholars that the shift may be unsustainable in the long run. That is, from the point of view of climate change mitigation, the goal should be to eliminate entirely the burning of soild fuel (firewood and charcoal), which is not the case and goal of the use of ICS, rather what it does is to imperove the lives of the urban poor (United Nations human Settlement programme, 2008). Nevertheless ICS offers good opportunities for poverty reduction, environmental protection and general socioeconomic wellbeing of the rural dwellers if they are effectively integrated into their everyday lives, at least in the short run.

4.3.1 Implication of climate change adaptation for Africa

In addition to the plethora of benefits from adaptation as has been x rayed in this paper, it is also heart-warming that a series of global modeling analyses show that the benefits from undertaking adaptation may outweigh the costs by a factor of about two in Africa (African Development Bank (AfDB) and African Development Fund (AfDF), 2011), thus giving hope for the future of climate change adaptation in the region. In addition it is evident that Africa possesses a wealth of social networks that have enabled people to survive throughout an environment of harsh climatic conditions. These networks represent safety nets for many of the people through compensation for their low financial incomes and helping many maintain their livelihoods. These networks should be built upon and further strengthened (Osman-Elasha, 2013).

Nevertheless, despite these successes stories, limited scientific capacity and other scientific resources which combine as factors to frustrate adaptation has been identified (Washington *et al.*, 2004, 2006). In addition evidence abounds in Africa of an erosion of coping and adaptive strategies as a result of varying land-use and biophysical changes and socio-political and cultural stresses. Thus, these traditional coping strategies may not be sufficient, either currently or in the future, and may lead to unsustainable responses in the longer term. Erosion of traditional coping responses not only reduces resilience to the next climatic shock but also to the full range of shocks and stresses to which the poor are exposed (DFID, 2004). These short-term responses and isolated projects good as they may be are not enough, rather long term solutions that could be considered include mainstreaming adaptation into national development processes (Huq and Reid, 2004; Dougherty and Osman, 2005). Boko *et al.* (2007) identified a complex range of factors, including behavioural economics (Grothmann and Patt, 2005), national aspirations and socio-political goals (Haddad, 2005), governance, civil and political rights and literacy, economic well-being and stability, demographic structure, global interconnectivity, institutional stability and well-being, and natural resource dependence (Adger and Vincent, 2005), as emerging and powerful determinants of vulnerability and the capacity to adapt to climate change.

In order to address some of these challenges, build resilience and strengthen adaptation capacity in Africa, several scholars have posited different options at the disposal of stakeholders, they are:

- Approaches that address multiple environmental stresses and factors hold the greatest promise for Africa, particularly given the limitations in capacity, in terms of both human capacity and financial resources. Efforts to design implementation strategies that address land degradation, loss of biological diversity and ecosystem services, as well as adaptation to climate change, such as through enhancing adaptive capacity, will be more likely to succeed than uncoordinated efforts (Osman-Elasha, 2013).
- Micro-financing and other social safety nets and social welfare grants, as a means to enhance adaptation to current and future shocks and stresses, may be successful in overcoming such constraints if supported by local institutional arrangements on a long-term sustainable basis (Ellis, 2003; Chigwada, 2005).
- Incorporating indigenous knowledge into climate change policies can lead to the development of effective adaptation strategies that are cost-effective, participatory and sustainable (Robinson and Herbert, 2001).
- A series of more targeted adaptation investments are required and it is crucial that African decision-makers factor climate change into all long term strategic decisions starting immediately (AfDB and AfDF, 2011).
- Adaptation needs to be complemented with global emission reductions. Although the policy focus in Africa is rightly on adaptation, the global need to reduce greenhouse gas emissions remains unchanged (AfDB and AfDF, 2011).

Thus, the successful implementation of some or all of these in addition to other development strategies that focus on enhancing the livelihoods of the rural people will go a long way towards enhancing the their ability to cope with climate change.

5.0 Conclusion

Rural households in Nigeria are dependent on forests for supplementing of their livelihoods; income from the forest ranges from about 14% in the Sudan savanna to 47% in the mangrove ecosystem. In addition to providing direct income to the rural dwellers, forest resources generate employment;

provide medicines and products for the urban population, international trade, social welfare and environmental benefits. Climate change impacts, particularly increased floods and erosion, erratic rainfall, high temperature, uncertainties in the onset of farming season, high disease and pest infestation, loss of soil fertility, strong wind and excessive rainfall in the south to severe water shortage in the north of Nigeria. Over 75% of the household agree that there have been adverse impacts of climate change, except in montane forests where the majority of the households (67%) assert that there have not been significant changes in forest resources. Among the adaptation options used by the households agroforestry is predominant; increased weeding, selective tree cutting, avoidance of burning, use of energy saving stove, watershed management, pruning, the use of local drip irrigation, changing planting dates, mulching, use of drought resistant varieties, increased spraying and plant replacement are also used.

There is no doubt that forest resources are an indispensable asset to the survival and livelihood of the rural West African households. Thus, adverse effect on forest resources will have serious consequences on the livelihoods and health of many households across Nigeria and the wider West African region. The adverse effects of climate change are already noticeable, with adaptation choices being made at the household level with concomitant observable social and economic progress. There is an urgent need for a concerted effort among stakeholders, to invest in adaptation options that are not just effective, but sustainable; e.g. agroforestry, irrigation and use of resistant varieties. In addition the information on the social perspectives of climate change as presented here are very useful in the hands of policy makers and development practitioners in formulating policies and strategies that are compatible with local norms and values. This will ensure a continuous flow of forest resources for the forest dependent poor.

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Appendices

Appendix 1. Climate change impacts explained

Impacts	**Meaning of the impact**
Delay in rainy season	Late onset of the rainy season
Less rain	Reduction in the total amount of rainfall per annum
Early rain followed by weeks of dryness	Rainfall starts early but followed by a dry spell
Erratic rainfall pattern	Rains at an unusual intervals resulting in difficulty in planning of farm activities
Heavy and prolonged rainfall	Very heavy non-stop rainfall that lasts for several hours, and in some cases days
Uncertainty in the onset of rainy season	It is difficult to predict when the rainy season will start
Longer dry season	The dry season period strhes longer than usual
Drought	Very severe dryness that results in lack of water and the death of plants and animals
Desertification	The spread of the desert, replacing arable/forest lands with sand
Drying up of streams and rivers	Streams and rivers drying up, either permanently or in the dry season
Heat waves	Chocking hot air blowing across towns causing extreme Discomfort
Higher temperature	Unusual increase in the temperature
Floods and erosion	Excessive run-off due to rainfall, causing flooding
Overflowing streams and rivers	Rise in the streams and rivers flowing over their banks
Thunderstorm	More frequent thunderstorms
No or reduced harmmattan	There is no harmmattan, or it lasts only for few days
Coloured and tasty water	Rain water is coloured or has some poor taste
High rate of disease incidence	Frequent outbreak of diseases, both for animals and crops
Increased pest infestation	Increase in crop pests incidence
Increased weed infestation	Excessive weed proliferation
Loss of soil fertility	Rapid degradation of the soil fertility, probably from nutrient loss

Appendix 2. Adaptation options explained

Adaptation option	Meaning
Agroforestry	Planting of trees within arable crops
Building of shades	Building of protective shelter for nursery, farm inputs, young plants or for farm workers
Increase use of fertilizers	The use of more fertilizers than usual due to declining soil fertility
Increased weeding	More frequent weeding than usual due to rapid weed proliferation, especially following excessive rainfall
Migration	Movement away from area of habitation to another area due to a variety of push factors
Planting deeper / shallower	Sowing planting material deeper or shallower primarily due to excessive heat or water logging respectively
Mulching	Covering sown seeds or base of seedlings with litters to protect them from sun burn / prevent evaporation
Planting more land area	Planting more land areas than usual to compensate for possible losses
Planting trees for shade	Planting trees to provide shade for crops at different stages of their growth
Plant replacement	Replacing dead plants with new seeds / seedling
Use of marginal lands	Use of less fertile lands that would ordinarily not be used for crop production
Use of resistant varieties	Use of plant species that can withstand adverse weather / disease situation
Use of wetlands	Putting wetlands into production to take advantage of water therein
Water-shade Management	Leaving a strip of forest between the cultivated farm and water bodies in order to protect the water from excessive evaporation and reduced drying up
Pruning	Systematic cutting off of some branches of trees to spur new branches / fruiting or keep in shape
Selective tree cutting	Leaving some trees with desirable attributes in the farm while clearing and cutting down others

Appendix 2: Adaptation options explained (continued)

Adaptation option	Meaning
Use of energy saving stove	The use of special kind of brick stove that utilizes less fuelwood, produces less smoke and conserves heat
Use of local drip irrigation	The use of perforated cans with water hung above seedlings to supply water in the field
Avoidance of burning	Avoiding burning fields to clear plant material
Changing farm activity times	Altering the usual time of farm activities due to adverse weather events
Changing to other businesses	Abandoning farming / forestry for other ventures
Erosion control	Building barriers to protect one's farm from erosion
Increase fallow period	Leaving the land to replenish by growing into bushes
Increase spraying	Increase quantity and frequency of spraying plants to protect them from pest and diseases
Use of irrigation	Using different irrigation schemes to supply water to the plants in the field
Do nothing	Leave the field to fate and implement no adaptation

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CHAPTER FOUR

Climate Change Impact on Forest Resource Use in Nigeria

4.1 Preface

Climate strongly influences forest productivity, species composition and the frequency and magnitude of disturbances, thus, a change in climate will impact directly and indirectly on forest resources in a number of ways. Direct impacts stem from an increase in the CO_2 concentration, temperature and / or precipitation changes, when indirect impacts come from the interactions between changes in climatic variables and abiotic and biotic factors (EFI, 2008). An analysis of the trend of rainfall and temperature in Nigeria using mean annual and monthly rainfall and temperature collected from 30 Nigerian Meteorological Stations and regional airports over the past 105 years (1901-2005) by Odjugo (2010) shows that the temperatures in Nigeria have been increasing. The temperature increase for the 105 years was 1.1^oC, which is higher than the global mean temperature increase of 0.74^oC recorded since 1860 (SPORE, 2008; IPCC 2007). Should this trend continue unabated, Nigeria may experience between the middle (2.5^oC) and high (4.5^oC) temperature increase by the year 2100 (Odjugo, 2010). Conversely the rainfall trend in Nigeria shows a general decline between 1901 and 2005, rainfall in Nigeria dropped by 81mm (Odjugo, 2010). Odjugo (2005; 2007) observe that the number of rain days dropped by 53% in the north-eastern Nigeria and 14% in the Niger-Delta Coastal areas. The declining rainfall became worst particularly from the early 1970s, a pattern that continues till date. This period of drastic rainfall decline corresponds with the period of sharp temperature rise. This is a clear evidence of climate change.

The foregoing trends have been linked to climate change, and its perceived impacts are already being felt by the forest resource dependent communities in Nigeria (Onyekuru and Marchant, 2014). Therefore, in this chapter, the economic impact of climate change was analyzed with the Ricardian model, by regressing net revenue from forest resources on climatic, agronomic and socioeconomic variables to estimate the marginal impact of climate change on forest resource use. Results are presented in a Paper titled; ‘Assessing the economic impact of climate change on forest resource use in Nigeria: a Ricardian approach’ that has been submitted for publication to the Journal of Agriculture and Forest Meteorology in June, 2014.

4.2 **Assessing the economic impact of climate change on forest resource use in Nigeria: a Ricardian approach**

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Abstract

Quantifying the impact of climate change at a regional scale is important in trying to develop adaptation policies. We estimated the economic impact of climate change on forest resource use in Nigeria using the Ricardian model in the STATA statistical software. Using a structured questionnaire, data were collected from 400 rural households in forest communities, sampled from five broad ecological regions across Nigeria to estimate income and potential impact on this as a result of climate change. Estimated average value of annual household income from the forest was $3380. The age of the household head, level of education, mode of transport, hydrology (river flow) significantly and positively affected net revenue from the forest, while noticing of climate change negatively affected net revenue. Also while winter and spring precipitation had positive impacts on net revenue ($1.5 and $0.28 respectively), summer and autumn precipitation had negative impacts; (-$0.073 and -$0.05 respectively). Marginal impact analysis shows that increasing rainfall during winter and spring seasons significantly increases the net revenue per household by $62 and $75 respectively, while increasing precipitation marginally during the summer and autumn seasons reduce the net revenue per household by $42 and $18 respectively. This underscores the place of rainfall as a limiting factor in tropical ecosystem productivity and the growing impact of changing rainfall on household income and efforts to moderate water supply in agriculture and forestry will be an effort in the right direction. Annual marginal increase in rainfall increases net revenue per household by $77. The model shows that a 1^{o}C increase in temperature will lead to an annual loss of \$39$\times 10^{-7}$in net income per household, after which further increase in temperature or decreases in precipitation shows no significant change in net revenue, thus underscoring the resilience of tropical forest to climate change.

Keywords; Agriculture, agroforestry, poverty, Tropical forest, West Africa.

1.0 Introduction

There is no doubt that recent trends in global climate change are having a negative impact on human and biophysical systems and will continue to do so into the near future (IPCC, 2007; 2014). Types of impacts include long-term water shortages, drought and desertification, disease and pest outbreaks, sea level rise, reduced crop production and economic decline (Kurukulasuriya and Rosenthal, 2003; IPCC, 2007). These impacts can be exacerbated by high levels of poverty, poor infrastructure and high population growth which limit the capacity of developing nations to manage climate change impacts (Bhandari *et al.*, 2010).

The impact will be more severe in a country like Nigeria due to the dependence on climate sensitive natural resource base – agriculture and forestry, upon which climate change is impacting. For many such developing countries like Nigeria, Bann (1997) asserts that forests represent an important resources base for economic development. Virtually every Nigerian is forest dependent, as there is no one in Nigeria that does not use one or several of forest products directly or indirectly. Forests provide households with income, fuelwood, food security, reducing vulnerability to shocks and adversities and generally increasing wellbeing (Arnold, 1998; Fisher and Shively, 2005; Eva and Fred, 2013, Onyekuru and Marchant, 2014). The forest foods are in the form of vegetables, fruits, nuts, tubers, seeds, oils, mushrooms, spices and drinks (alcoholic and non-alcoholic). Indigenous population in Nigeria have benefited historically from these natural ecosystems products through the use of Non Timber Forest Products (NTFPs). Specifically the level of dependence on these products ranges from an average of 14% in the Sudan savannah to 47% in the mangrove, with a range of 5 to 95% (Onyekuru and Marchant, 2014). Osemobo, (2005) found that the average annual value of harvested wild products from the Nigerian forests per household was US$6,742, while Onyekuru and Marchant (2014) found it to be US$11,956, showing a remarkable increase of almost double in less than a decade. Thus, there is no doubt that the impact of global climate change will therefore have consequence for the livelihoods of those who depend on the forest for their daily survival.

As in most tropical regions, all seasons in West Africa are increasingly going to be warmer by the end of the 21st century, under the A1B scenario, the median temperature is projected to increase by between 3°C and 4°C; roughly 1.5 times the global mean (Hiraldo, 2011; Christensen *et al.*, 2007). Specifically, in Nigeria the impacts are already being felt in different regions. It is estimated that Nigeria is losing about 73% due to desertification, out of the estimated total cost of about US$5.11

billionyr^{-1} due to environmental degradation (Federal Government of Nigeria, 1999), whilst deforestation is taking place at 3.5%yr^{-1} (IITA, 2010). The Sudan Sahel region of Nigeria has suffered a 3-4% decrease in rainfall per decade since the beginning of the 19th century (Brown, 2006). Although there have been a number of projections about the re-greening trend of the Sahara in some places (Anyamba and Tucker 2005; Stefanie *et al.,* 2005; Olsson *et al.,* 2005; Nicholson, 2013; Jury and Chiao, 2014), although its causes, extent and longevity are still under investigation. In recent times the southern part of Nigeria, has experienced increased amount of rainfall which is irregular while the north are experiencing dryer weather (Onyekuru and Marchant, 2014) and more rainfall is projected to increase roughly by 20% at the end of the 21st century compared to 5% in the late 20th century (Christensen *et al.*, 2007). Projections also show that many parts of southern Nigeria will continue to see more torrential rains and windstorms becoming harsher and more common, while the arid north are facing more heat and less rain (Obioha 2008, Sayne, 2011, Abiodun, 2013). Along the southern coastline an increase of over 1-foot rise has been observed in the last fifty year and sea levels could rise 1.5 to 3 feet by century's end (Sayne, 2011). With a coastline that is more than 800 km long, it has been predicted that Nigeria will lose close to $9 billion as a result of sea-level rise while, at least, 80% of the inhabitants of the Niger Delta will be displaced due to the low level of the oil-rich region (Uyigue and Taylor, 2007). Yet Nigeria's national capability for assessing, forecasting, and planning for climate change remains inadequate. So, rather than annual decline, OECD (2009) argues that water crises in West Africa relates to high inter-annual and inter-decadal rainfall variability and uncertainty poses major problems in terms of water availability in the desired time and place. This is a very big concern for the rainfall dependent agriculture in Nigeria with respect to planning of farming and forest activities, due to uncertainty in the unset of rainy season, flood and rainstorm, which are already serious challenges facing most communities in Nigeria (Onyekuru and Marchant, 2014).

It is therefore based on the premise of the forgoing concerns that this study was borne. The study was set out to estimate the economic impact of climate change using the Ricardian model. Specifically the marginal impacts of seasonal temperature and rainfall on forest net revenue were estimated. Furthermore, different future climate scenarios were used to forecast the magnitude of climate change impact on forest net revenue per household.

To analyze the impact of climate change on agriculture and land use, several methods have been used, including the agricultural ecological zone method, agronomic – economic method and the Ricardian model (Mendelsohn *et al*., 1994; Wood and Mendelsohn, 2014) . The Ricardian approach as is applied in this analysis has been used to predict the damages from climate change in the US

(Mendelsohn *et al.*, 1994, 2001; Mendelsohn and Nordhaus, 1996; Mendelsohn and Neumann, 1999), on farm net revenue in Egypt (Eid *et al.*, 2006); on cropland in eleven African countries (Kurukulasuriya and Mendelsonn, 2008), in Brazil and India (Dinar *et al.*, 1998; Kumar and Parikh, 2001; Mendelsohn *et al.*, 2001), in Canada (Reinsborough, 2003) as well as on irrigated rice agriculture (Ajetomobi, *et al*., 2010) and plantation agriculture in Nigeria (Fonta, *et al.,* 2011). In the case of the studies in Nigeria they were limited to specific crops, which tend to overestimate damages as forecasts of the impact of climate on agriculture cannot rely solely on how climate affects the yield of a specific crop, but must also capture crop switching (Mendelsohn *et al*., 1994; Seo and Mendelsohn, 2007). That is, the forecasts must recognize that farmers will change what they plant in order to maximize profits in each new climate (Seo and Mendelsohn, 2007). To date no study has focused on estimating the economic impact of climate change on forest resource uses; particularly using a unifying methodology across different agricultural zones. Given the critical role forest resources play in the economic and social lives of Nigerians, and the need to build the resilience of forest communities for the sustenance of the people of Nigeria (Fig. 1).

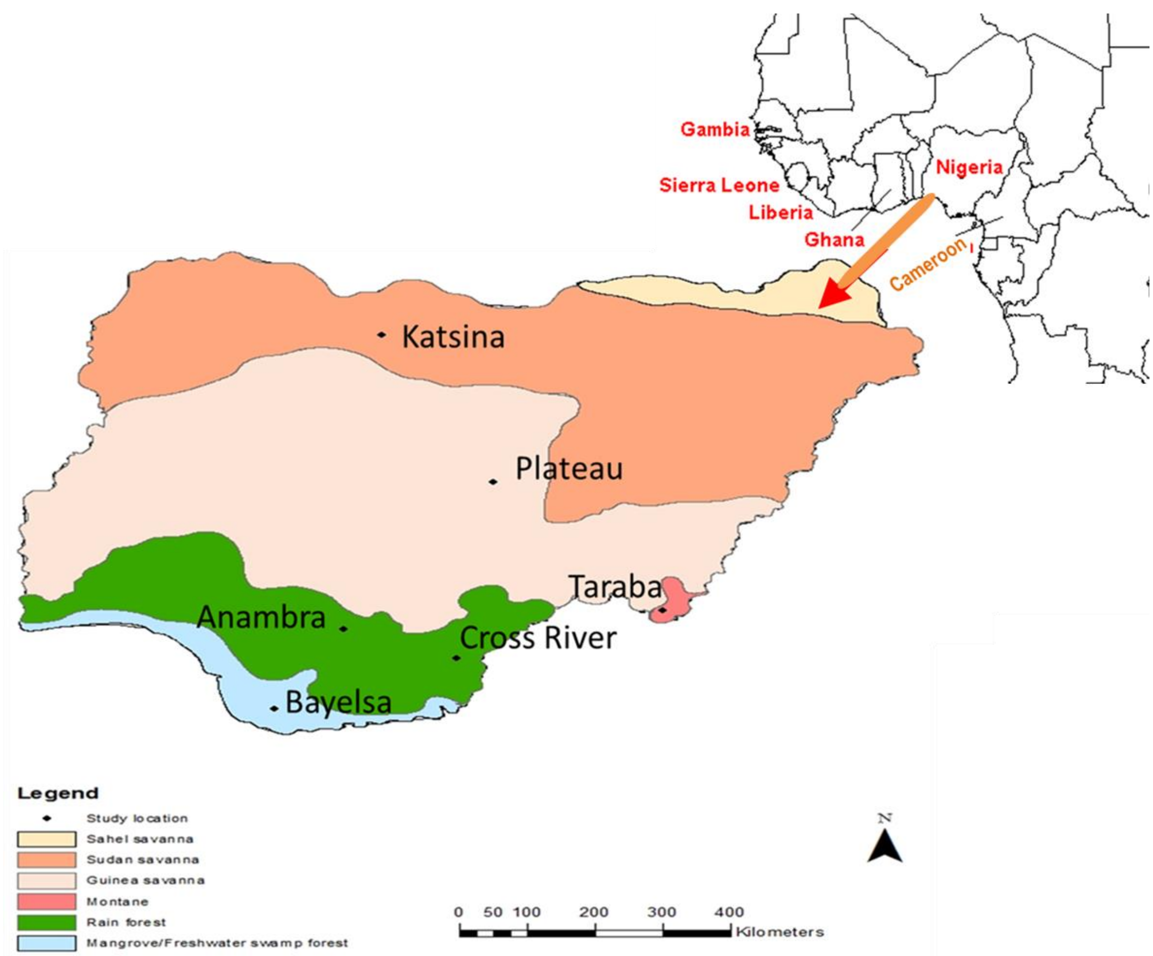

Figure 1. Agro ecological map of Nigeria showing places used for the study

2.0 Theoretical and analytical frameworks

2.1 Application of the Ricardian Model

The Ricardian model is a model that can be used to measure the impacts of climate change on agriculture (Mendelsohn *et al.,* 1994). The technique was developed after the work of Ricardo (1817) on land rent; it first estimates the impact of climate on agricultural land values (rent) and then predicts the impacts of climate change on agriculture using the estimated relationship. On the common principles of supply and demand, no rent is paid for any land or nothing is given for the use of air and water, or for any other of the 'gifts of nature'. If land were unlimited in quantity and uniform in quality, no charge could be made for its use, unless where it possessed peculiar advantages over other pieces of land (Ricardo, 1817; Mendelsohn *et al.,* 1994). If air, water and the pressure of the atmosphere could be commoditized, and each quality existed only in moderate abundance, they, as well as the land, would afford a rent, as the successive qualities were brought into use. With decreasing quality, the value of the commodities would rise. As land is not unlimited in quantity and uniform in quality, and because in the progress of population, land of an inferior quality or less advantageously situated, is called into cultivation, that rent is paid. When land of the second degree of fertility is taken into cultivation, rent immediately commences on that of the first quality, and the amount of that rent will depend on the difference in the quality of the first and second portions of land. When land of the third quality is taken into cultivation, rent immediately commences on the second, and it is regulated as before, by the difference in their productive powers, and so on. At the same time, the rent of the first quality will rise, for that must always be above the rent of the second, by the difference between the produce which they yield with a given quantity of capital, labour and other exogenous variables (Ricardo, 1817; Mendelsohn *et al.,* 1994). By this theory Ricardo clearly puts the value of whatever is the product of land as the rent paid for the use of the land by the producer.

The most important advantage of the Ricardian approach is its ability to capture the adaptation that farmers make in response to local environmental conditions. It captures the actual response rather than the controlled ones. In addition, it is capable of capturing the farmers' choices over crop mix instead of yield (Liu *et al.,* 2004). The value of the change in the environmental variables is captured exactly by the change in land values across different conditions. Cross-sectional observation, where normal climate and edaphic factors vary, can hence be utilized to estimate farmer-adapted climate impacts on production and land value. Then the estimated parameters from the Ricardian are used to simulate climate change impacts based on a set of climate change scenarios and make projections for the future. The projections are intended to provide a sense of the impact of climate change in the future (Seo and Mendelsohn, 2008a). Crop net revenue has been found to be sensitive to seasonal precipitation and temperature (Kurukulasuirya *et al.,* 2006) and livestock net revenue (Seo and Mendelsohn, 2008b; 2008c). Similar results have also been found in several other studies for land value per hectare of cropland (Mendelsohn *et al.*, 1994, Mendelsohn and Neumann, 1999; Dinar *et al*., 1998; Mendelsohn 2001; Mendelsohn and Dinar, 2003; Seo *et al.*, 2005; Seo and Mendelsohn, 2008d).Thus, Liu *et al.*, (2004) assert that climate has a great impact on production and land value. Related to this study is the estimation of the impact of climate change on plantation agriculture in Nigeria (Fonta *et al*., 2011). This study goes further to look at not just plantation agriculture but the entire forest resource use in Nigeria.

2.2 Analytical Framework

Three methods have been developed to measure the impact of climate on systems: agro-ecological zone (AEZ), agronomic-economic model and cross-sectional model, model (FAO, 2000).

2.2.1 Agricultural Ecological Zone Method

The AEZ model relies on environment – crop relationships to simulate crop yields, rather than measured crop yields. The AEZ model was developed to look at potential production capacity across various ecological zones. The biggest advantage associated with the agro-ecological zone approach is that they have been measured and published for all developing countries (FAO, 1992) and has been used by several scholars (Fischer *et al.*, 2001; 2005) to estimate climate change impact. Its weakness is that it shows a lack of reliable and accurate yield data on a widespread basis. But technology adoption, as well as adaptation to climate change specific impacts can be captured in the AEZ by generating static scenarios with changes in technological parameters.

2.2.2 Agronomic-Economic Method

The traditional approach for estimating the impact of climate change relies upon empirical or experimental production functions to predict environmental damage; hence it is also called the production-function approach (Mendelsohn *et al.*, 1994). The agronomic-economic method begins with a crop model that has been calibrated from carefully controlled agronomic experiments in the field or laboratory settings under different possible future climates and CO_2 levels, so that all differences in outcomes can be assigned climate variables (temperature, precipitation, or CO_2). The changes in yields are then entered into economic models that predict aggregate crop outputs and prices. The model is difficult to apply to developing countries; first, it has been criticized for underestimating adaptive responses to changing climate, since it is crop specific and does not take account of switching (Mendelsohn and Neumann, 1999). Second, there have not been sufficient experiments to determine agronomic responses in most developing countries. Finally, economic models of developing country agriculture are poorly calibrated.

The agro-ecological zone and the agronomic-economic models thought provide a useful baseline for estimating the impact of climate change on farming; have an inherent bias and will tend to overestimate the damage. Mendelsohn *et al.,* (1994) refer to this bias as the "dumb-farmer scenario" to suggest that they omit a variety of the adaptations that farmers customarily make in response to changing economic and environmental conditions as no changes are permitted to farming methods across experimental conditions. Production function approach will overestimate the damages from climate change because it does not and indeed cannot, take into account the infinite variety of substitutions and adaptations (Mendelsohn *et al.,* 1994). The experiments are costly so that few locations can be tested. This raises a question about whether the experiments are representative of the entire farm sector (FAO, 2000). They do not consider the introduction of completely new crop or technological change. Specifically, the bias in the production-function approach arises because it fails to allow for economic substitution as conditions change. This is problematic because climate change will not impact agricultural systems for decades. By the time climate actually changes, the farming systems could dramatically evolve from their current form. It is therefore important to capture the technical change in the farming system in order to predict what climate change will do when it occurs (FAO, 2000). These gap in the above two models are what this work fills by using the Ricardian model.

2.2.3 Cross-Sectional Method – Ricardian model

The Ricardian model in principle corrects for the bias in the production-function technique by using economic data on the value of land. It examines farm performance across climate zones (Mendelsohn *et al*., 1994). By regressing land value on a set of environmental inputs, one can measure the marginal contribution of each input to farm income. The most important advantage of the Ricardian approach is its ability to incorporate efficient private adaptation response by farmers to local climate and direct effect of climate on productivity. Private adaptation involves changes that farmers have made to tailor their operations to their environment in order to increase profits. Depending on the climate a given crop will be optimal; as climate changes, the farmer would change crops or technique. The estimated parameters from the Ricardian regressions can be used to simulate climate change impacts based on a set of climate change scenarios for the future to provide a sense of how climate change will impact agriculture (Seo and Mendelsohn, 2008a).

The Ricardian model uses rent as the value of land, though in later studies net revenue have been used due to the problem of getting (or calculating) actual rent in most developing countries. If use *i* is the best use for the land

Li = the quantity of output from the land
E = the environment variable (temperature and rainfall)
R = factor prices (unit price of the output)

The observed market rent of the land will be equal to the annual net profit from the production of output M *i*, therefore, land rent per hectare is equal to net revenue per hectare (Dinar *et al.,* 1998). Net revenue is calculated as gross revenue (production for each product multiplied by the price for that product) minus costs (the monetized cost required to produce the given amount):

$$pL = [PiQi - Ci(Qi,R,E)]/Li \qquad (1)$$

Where *pL* is land rent per hectare, *Pi* and *Qi* are respectively the price and quantity of crop *i*, *Ci( )* is the function of all purchase inputs other than land. *R* = [*R*1......*Rj*] is the vector of factor prices, *E* is an exogenous environmental input into the production of goods, e.g., temperature, precipitation, and soils, which would be the same for different goods produced under the same or similar conditions; in this case same ecological zone. For this analysis, these variable (rainfall and temperature are the means of monthly rainfall and temperature from 1970 to 2010, for five ecological regions of Nigeria – mangrove, rainforest, Guinea savanna, Sudan savanna and the montane forest (apart from the Sahel, due to its inability to support productive forests and agriculture), spread across the length and breadth of Nigeria, from the coast of the Atlantic ocean in the south to the shore of the Sahara in the north. The soil variables are the different soil types of the different ecological regions used in the analysis,

Evidence suggests that the relationship between climate variables and land value is assumed to be quadratic (hill-shaped), so that the climate vector includes squared terms. Because the effect of climate on land value varies across seasons (Mendelsohn *et al.,* 1994), temperature and precipitation are introduced for each of four seasons. For each variable, linear and quadratic terms are included to reflect the nonlinearities that are apparent from field studies. Moreover, the quadratic climate variables are easier to interpret. The linear term reflects the marginal value of climate evaluated at the mean, while the quadratic term shows how that marginal effect will change as one moves away from the mean. In the remainder of regressions, soil, socioeconomic and other environmental variables are included to control for extraneous factors influencing land values and farm revenues. Socioeconomic and soil variables play a role in determining the value of farms. The standard Ricardian model relies on a quadratic formulation of climate (Dinar *et al*. 1998) thus:

pL (Net revenue/household) $= \beta0 + \beta1\ F + \beta2\ F^2 + \beta3\ Z + \beta4\ G + u$ …………………….… (2)

Where: Rent/ha = rent/hectare; F = vector of climate variables; Z = set of soil variables; G = set of socio-economic variables and u = error term (**normally distributed error term**).

The earlier Ricardian studies did not include irrigation in the analysis. However, application in United States data by Mendelsohn and Dinar (1999) suggests that water supply from runoff has an important effect on farms. In Nigeria, some farmers, especially in the north use irrigation for their production. Therefore, modelling hydrology (runoff or river flow) across Nigeria could reveal the extent to which runoff affects existing farms. Furthermore, it can explicitly capture how runoff changes would interact with direct climate changes and affect farms in the future. The following model is proposed:

Rent/ha (Net revenue) $= \beta0 + \beta1\ F + \beta2\ F^2 + \beta3\ Z + \beta4\ G + \beta5\ H$ ……………………….. (3)
Where: H = relevant hydrology variables.

Dependent variable

Due to the difficulty in getting the value of rent from our typical African setting as a result of the low level of organization in the land market net revenue from the forest per household was used as the dependent variable as in most of Ricardian analysis. In addition, the use of net revenue instead of land rent is intuitive in the forest sector as output of the land is weighed not per land unit basis, but per person / household, as was described by the respondents; that most of the forest resources occur in family and community lands in different fragmentations, which is the case in typical rural African settings. So it becomes very difficult to assign the produce to any particular land area. Secondly, several outputs come from the same piece of land and occur or are harvested in a continuum by different individuals and at different or same times in the year. Net revenue was computed from equation 1, by aggregating all the revenue items and the cost items, including depreciation and netting out total cost from the total revenue.

Explanatory variables

Climate data: Average temperature and precipitation from Nigerian Meteorological Agency (NIMET) are used. NIMET has over 36 meteorological stations in different states of Nigeria. For the analysis, data from five locations (in this case the nearest station to each of the study areas), where the study was conducted were used for the analysis. The climate variable inputs for the temperature and precipitation used in the analysis were computed by taking the means of the monthly values of each from 1970 to 2010, and the values coded against each sampling unit in the model in the corresponding zones.

Soil data: Soil data from the department of Soil Science, University of Nigeria Nsukka provide information about the different soil types of the different states and regions of Nigeria. The use of soil variables (dummies0 for each zone here also doubles as a fixed effect for the different zones. The different soil types of the different locations were inputted as dummies in the model, each value coded against each of the sampling units in the respective zones. This was to enable us understand the effect due to different soil types of the different zones in the modeling process (in other words, regional effects).

Socio-economic Primary survey was conducted by the research team and socio economic data from the survey *inter alia* are household size, age, gender, number of years of forest use, level of education, occupation, distance to market to buy inputs, total cost for farm labour, access to electricity, amount of products sold, consumed by livestock, consumed by household and contact with extension officers.

Hydrology data: Hydrology is the movement of water in relation to land, measured in meter per second (m/s), in other words river flow or run off. The earlier Ricardian studies did not include irrigation in the analysis. However, initial research on US data by Mendelsohn and Dinar (1999) suggest that water supply is very important to farms, especially in rainfall dependent systems like Nigeria. Thus, farms that can draw water from runoff are more likely to be irrigated (Eid, *et al*., 2007). Hydrology data was collected from the Global Runoff Data Centre, D - 56002 Koblenz, Germany

3.0 Materials and methods00

3.1 Sampling technique for the survey

Using a structured questionnaire (Appendix 1) data were collected from 450 rural households in 2011, sampled from five broad ecological regions in Nigeria (Fig.1) to assess the socio economic attributes of respondents and forest resource use. By taking a proportion of the relative size of the population which they support, and the prevalence of forest cover, 150, 100, 100, 50 and 50 households were sampled from the rainforest, mangrove forest, Guinea Savanna, montane forest and Sudan savanna zones respectively (Table 1).

Table 1: Towns used for the study in each ecological zone

Ecological zone	State	Town
Mangrove	Bayelsa	Koroama, Okolobiri, Obuna, Polaku and Nedugo
Rainforest (Dense)	Cross River	Nsak, Okuni and Urban
Rainforest (Sparse)	Anambra	Isi Achina and Umuchu
Guinea Savanna	Plateau	Riyom, Mangu, Kanke
Montane	Taraba	Garin dogo Zau. Lushi garin dogo zau, Gang Bentsa-Dakka and Gani-Dogo Lau
Sudan Savanna	Katsina	Daddara and Jibia

For the rainforest zone the Cross River high forest was chosen as this is the only area of surviving lowland rainforest cover, not just in Nigeria, but across West Africa. Communities were selected based on information from local informants on their reliance on forest resources. Five communities were selected from each of the rainforest and mangrove forest areas, four from Guinea Savanna, three from montane and two from Sudan savanna ecozone. Communities were chosen using a random draw from all possible communities in the target areas. In each community households were randomly selected using the communities' roll calls. From the roll call, different households were selected at random intervals until the required number of households per community was reached (this was directly proportional to the total population of the different communities). Using research assistants in the different areas who could understand the local languages structured questionnaires were administered on a one to one basis, with the household heads, or other knowledgeable members of the households, who were conversant with forest resource use by the household and the wider community. To check for interviewer bias and ensure data consistency and compatibility, the addresses and mobile phone numbers of each respondent were collected and information supplied by the interviewer randomly cross checked in all zones. For any missing information on each questionnaire efforts were made to get back to the respondents in person or on phone to verify and complete them until 400 questionnaires were fully completed. The data collected were coded, screened and analyzed using STATA statistical software. At the end of the screening 50 questionnaires were discarded for not having complete information required for the analysis and for lack of consistency and 400 were used for the analysis.

3.2 Analytical procedure

Ordinary Least Square estimation procedures using the STATA software was used to fit the Ricardian model. Both the linear and quadratic forms of the model were run in order to understand the actual behavior of each of the variables in each condition, especially for the dummy variables (mode of transportation, notice of climate change and the different soil variable), which were dropped out in the quadratic estimation. The error term was found to be heteroskedastic after test, thus, to overcome this problem a robust estimation of the standard errors was undertaken. To overcome the problem of multicollinearity, identified correlated variables were dropped automatically by STATA. The marginal impact of seasonal temperature was estimated for the proposed model. Furthermore, scenarios of different temperature and rainfall variables, as forecasted by three Atmospheric Oceanic General Circulation Models (AOGCMs) (Canadian General Circulation model (CGM2), Hadley Centre Coupled Model version 3 (HadCM3) and Parallel Climate Model (PCM) for 2050 and 2100) (Table 2) were used to forecast the magnitude of climate change on net revenue per household.

Table 2: Specifications of Atmospheric Oceanic General Circulation Models (AOGCMs)

Model	**Temperature (^{o}C)**		**Rainfall (%)**	
	2050	2100	2050	2100
CGM2	+3.26	+8.01	-12	-26.5
HaDCM3	+3.2	+9.41	-6.75	-16.69
PCM	+2.25	+5.44	-4.06	-8.9

These models are among the set of state-of-the-art coupled climate models used by the IPCC (2001) and in their projections for West Africa in the Third Assessment Working Group 1 Report (Tornton *et al.,* 2006) and provide an overview of current and future climate trends and indications of climate induced risks. These climate change scenario data of these GCM-SRES combinations was extracted from the TYN CY 3.0 data set of the Tyndall Centre for Climate Change, which offers country basis data on changes per month (precipitation in mm; temperature in °C) at the end of the 21st century relative to a baseline period (1961–90) (Kassie *et al.*, 2013; Mitchell *et al.* 2004). Moreover these models (CGM2, HaDCM3 and PCM) have been shown to suggest decline in future net revenue per hectare for plantation crops in Nigeria (Fonta *et al*., 2011). For each climate scenario, the change in temperature predicted by each climate model was added to the baseline temperature in each region, the percentage precipitation change predicted by each climate model was multiplied by the baseline precipitation in each region and the model rerun.

4.0 Results

The data summary (Table 3) shows that most of the variables have low standard deviation, indicating data homogeneity.

Table 3: summary of different variables used in the model

Variable	Description	N	Mean	SD	Min	Max
Hhsize	Household size (number)	400	4.21	2.56	1	9
Gender	Gender (male =1, female = 0)	400	0.73	0.44	0	1
Age	Age (yrs)	400	48.55	13.98	18	86
educ1	Level Education (yrs)	400	9.39	5.27	0	25
Hhelectric	Electricity in the house (yes=1, no= 0)	400	0.59	0.49	0	1
Priocupaton	Pri. occupation (farmer = 1, others = 0)	400	0.75	1.05	0	1
Foruseyrs	Number of years of forest use (yrs)	400	19.91	10.73	1	60
Distpmkt	Distance to market (minutes)	400	39.58	22.74	5	90
Mkttrans	Transport mode to market (Motor =1, trekking = 0)	400	0.66	0.48	0	1
Nr	Net revenue per household (Naira)	400	307893	532373	5000	5500000
Extcvisit	Number extension contact (number)	400	0.51	2.65	0	24
Noticecc	Notice of climate change (ye = 1, no= 0)	400	0.88	0.32	0	1
Springt	Spring temperature	400	33.30	2.41	29.89	37.92
Summert	Summer temperature	400	29.34	2.06	25.12	32.87
Autumn	Autumn temperature	400	30.68	1.76	27.31	33.51
Winter	Winter temperature	400	32.53	2.23	28.26	35.52
Springp	Spring precipitation	400	138.97	67.23	21.43	222.98
Summerp	summer precipitation	400	283.21	97.59	164.37	419.94
Autumn	Autumn precipitation	400	179.45	88.75	37.05	285.13
Winter	Winter precipitation	400	19.30	18.55	0	40.98
flow_mean	Hydrology (m/s)	400	3378.67	1742.2	982.59	5096.3
Sulphaqueps ts	Bayelsa Soil	400	0.22	0.39	0	0.9
Ferrallitic	Cross River and Anambra soil	400	0.23	0.39	0	0.9
Ferruginous	Taraba soil	400	0.23	0.40	0	0.9
Ferruginous	Plateau soil	400	0.11	0.30	0	0.9
Reddish Brown	Katsina soil	400	0.11	0.30	0	0.9

The only exception was net revenue which has a very high standard deviation. This is not surprising due to the very wide gap between the lowest and highest income (₦5,000 ($33) and ₦5,500,000 ($37,000) respectively). This is expected owing to the level of involvement of different individuals in forest resource exploitation; while some engage in it as full time employment, others combine it on part time basis. In addition, the level of species richness and abundance of forest products differ across the country from the mangrove in the south to the Sahel in the north; decreasing from the former (average of ₦573,418 ($3,822) to the later (average of ₦175,500 ($1,170)) respectively (Table 4) (calculated from equ. 1). So the relative income from the different zones and households differs substantially from each other.

Table 4: Average household net revenue per zone per annum (₦)

Ecological zone	**Net revenue**
Mangrove	573,418
Rainforest (dense)	492,940
Rainforest (sparse)	141,630
Guinea Savanna	259,265
Montane	175,510
Sudan Savanna	175,500

The Ricardian model estimates the impact of climate and other variables on the capitalized value of cropland. In this analysis we regressed net revenues per household from forest resources (Table 4) as dependent variable against other climatic, soil and demographic variables. The independent variables include the linear and quadratic temperature and precipitation terms for the four seasons: winter (December, January and February), summer (the average for June, July and August), spring (March, April and May) and autumn (the average for September, October and November) (Appendices 2 and 3).

The independent variables include household attributes and soil types. The household variables are level of education and age of the household head, distance to markets, number of contact with extension officers, primary occupation, gender, mode of transportation to market, having electricity in the household and household size. The soil variables are the different soil types in the different locations used for the study. After the model run, some of the variables, including temperature were dropped automatically due to multicollinearity and the non-significant variables were also dropped from the analysis.

The regression results indicate that age of the household head, level of education, mode of transport, hydrology (river flow) significantly and positively affected net revenue from the forest, while notice of climate change negatively affected net revenue. While winter and spring precipitation also had positive impact on net revenue, summer and autumn precipitation had negative impacts (Tables 5 and 6).

Table 5: Model result of climate and control variables

	Coef	Std. Err.	t	P>|t|
Education	11194	51129.94	2.27	0.03
Age	4656.8	1911.96	2.58	0.01
Winter r/fall	14131.8	3122.37	4.57	0
Spring r/fall	265.79	2426.89	0.11	0
Summer r/fall[[	-2470.96	1195.48	-2.039	0.05
Autumn r/fall	-1955.11	1127.33	-1.71	0.08
Education 2	658.02	262.98	2.43	0.014
Age2	50.84	23.42	2.17	40.031
Winter r/fall2	228.46	81.61	2.68	0
Spring r/fall2	42.18	19.2	2.19	0.008
Summer r/fall[[2	-11.54	4.47	-2.43	0.039
Autumn r/fall2	-7.69	3.74	-1.95	0.012
Transport mode	136783.3	64179.21	2.24	0.03
Notice cc	-142.689	83207.35	-1.7	0.09
River flow	234.33	51.15	4.573	0
Bayelsa soil	296173	85640.85	3.446	0
Cross river soil	-79487.9	83376.79	-0.953	0.35
Plateau soil	-40715	102202.2	-0.374	0.79
Katsina soil	24699.49	113720.8	0.215	0.86
Constant	286565.1	83204.11	3.44	0.06
N	400		F	6.65
R-Square	13		Prob > F	0

Table 6: Model result of climate variable alone

Variable	Coef.	Std. Err.	T	P>|t|
winter r/fall	14353.45	3421.357	4.24	0
spring r/fall	3756.44	1532.39	2.59	0.006
summer r/fall	-3554.29	950.028	-3.87	0
Autumn r/fall	-1212.31	782.88	-1.54	0.114
winter r/fall2	249.29	78.04	3.19	0.002
spring r/fall2	33.7	17.04	1.9	0.053
summer r/fall2	-9.61	4.08	-2.3	0.025
Autumn r/fall2	-6.56	3.99	-1.7	0.087
_cons	420827.9	93778.51	4.55	0
N	400		Prob > F	0
R-Square	0.095		F	9.03

Marginal impact analysis was undertaken to observe the effect of change in climatic variables on net revenue (Table 7). The result shows that increasing temperature during winter and spring seasons significantly increases the net revenue per household, while increasing precipitation marginally during the summer and autumn seasons reduces the net revenue per household. Overall, marginal increases in rainfall have a favourable impact on net revenue per household.

Table 7: Marginal impact of climate variables on net revenue per household

Variable	Coef.	Std. Err.	T	P>(t)
Winter precipitation	9414.06	3355.11	2.81	0.005
Spring precipitation	11375.62	5662.88	2.01	0.045
Summer Precipitation	-6333.38	2734.97	-2.32	0.021
Autumn precipitation	-2818.43	1541.53	-1.83	0.068
Annual precipitation marginal effect				
Annual precipitation	11637.87	2680.22	4.34	0.001

For the scenario analysis, the temperature and rainfall variables were increased and decreased respectively by different amounts according to AOGCM outputs, as shown in table 2. In the uniform scenario, an increase in temperature by 1^{o}C will lead to negligible annual loss of USD39 x 10^{-7} in net income per household per year, same as a 7% decrease in rainfall, after which further increase in temperature or decrease in precipitation shows no significant change in net revenue from the forest. The predicted average value of household income from the forest/annum (Y – hat) was estimated to be ₦507, 023.72 ($3380). This is the expected average future household earning stream from the forest per annum.

5.0 Discussion

The education level of the head of the household is significant and positively related to the net revenue per household, this is in agreement with the findings of Deressa (2007) in Ethiopia, Ajetomobi *et al.* (2010) in rice agriculture in Nigeria and in plantation agriculture in Nigeria (Fonta *et al.*, 2011). This relativity between the level of education of the household head and net income is not surprising as the educated are more innovative in forest management and enlightened about the best techniques to boost output, especially those that are involved in agroforestry, which was found to be a predominant practice in all the study areas. For the case of age, this may be a reflection of the young people who leave the villages for better opportunities in the cities, thereby having the older people to be more involved in forest activities. In addition, older household heads are associated with larger family sizes in villages who are involved in the collection of forest products, especially for the communal forests, thus the higher the number of people collecting, the higher the revenue accruing to the households. Mode of transportation was shown to be significant and positively related to income, implying that those who use motorized means of transport to go to the market are better off, as they make more money than those who trek to the markets. This is very intuitive due to the fact that those who use vehicles to the market probably can extract more from the forest, sale more, especially in urban markets and make better margins than those who trek to the market, who can only carry and sale little, probably in rural markets where there are usually glut and mostly low priced.

Noticing of climate change was shown to be significant and negatively related to income. The result is in agreement with *a priori* expectations on the sign of the variable. This shows that those who have experienced severe impact of climate change; excessive rainfall, flooding, high temperature, low rain, desertification and so on have had less income from the forest than those who have not had such experiences, as was show to be the case in the montane regions of Nigeria (Onyekuru and Marchant 2014). Thus the higher the incidence of climate change impacts, the higher the ability of individuals to notice it and the more the effects on their output. In some cases the impact could be directly affecting the output or affecting the ability of the people to access the products, like when there is excessive rainfall or flood.

Hydrology variable (river flow) was show to be significant and positively related to net revenue. This result is also in agreement with *a priori* expectations as the higher the river flow of the different rivers the higher the volume of water available for supply to the forests and for irrigation in the case of those that could utilize it. Thus increased river floor is a positive thing for the forests due to the increased availability of soil moisture for their production.

Increasing precipitation during the winter (dry) season and spring (early rainy) season increases net revenue per household by ₦9,414.06 ($62) and ₦11,375.62 ($75) respectively. It is noteworthy that this level of increase in revenue will be more significant for the less income households than the higher ones; considering that the net income of households from the forest differs from as little as $33 to $37000. This result is in agreement with that of Mendelsohn and Dinar (1999) who found that increase in winter precipitation has positive impact on net revenue in India and Brazil. During these periods the amount of rainfall is low and does not inhibit access and collection of forest products, it is during this period that most fruit trees are harvested and the wild vegetables flourish. Also with slightly higher temperature and available precipitation (soil moisture level) during the early cropping season (spring) for those involved in agroforestry, crop germination is enhanced, leading to bumper harvest. The result underscores the need for improved irrigation in the system as an increase in water supply during this period will boost agriculture.

On the contrary, marginal increases in precipitation during the summer (peak) rain and autumn seasons especially in the southern part of Nigeria where most of the forest resources are produced, reduces net revenue per household by ₦6333.38 ($42) and ₦2818.48 ($18) respectively. The result also agrees with that of Mendelsohn and Dinar (1999) in India and Brazil that increase in summer precipitation had negative impact on net revenue. Increase in rainfall during the rainy season inhibits access to forest for the collection of forest products. In addition the reduction is due to the already high level of rainfall in the country during this season, as further increases in precipitation result in flooding and damage to fruits, leaves, trees and crops, and during the autumn, increasing precipitation is detrimental to crop and fruit production due to the reduced water requirement during the harvesting season (Marshall *et al.*, 2002; NeSmith, 2005; Johnson, 2013; Sosnowski, 2013). More precipitation will be damaging and may reinitiate vegetative growth during this season, when ordinarily during autumn, a drier environment dries up the crops and facilitates harvesting. These results on positive impact of precipitation during the spring and adverse impact in the summer and autumn are also in agreement with works on plantation agriculture in Nigeria (Fonta *et al.*, 2011), on cocoa production in Nigeria (Lawal and Emaku, 2007), in African cropland (Kurukulasuriya and Mendelsohn, 2008) and on Ethiopian Agriculture (Deressa, 2007).

In the case of soil variable, only the soil of the mangrove region was significant and positively related to net income from the forest. This is not surprising as this area was shown to be the area with the highest percentage contribution (average of 47%) of forest products to livelihood and support a lot of biodiversity ranging from the mangrove, to fresh water swamp, to the rich rainforest periphery (Onyekuru and Marchant, 2014). This could be due to the rich alluvial deposits that inundate the area from time to time, which constantly replenish the soil.

In the climate change uniform scenario analysis, the result shows that an increase in temperature by 1^{o}C and a decrease in rainfall by 7% will lead to very little annual loss in net income per household; \$39×10^{-7}, this is very negligible. Further increase in temperature and reduction in rainfall as is the case in the different scenarios show no significant change in net revenue from the forest. This result may be associated with the resilience of the tropical forests to adverse climatic variations, unlike conventional cropping systems that are at the mercy of the vagaries of nature. The tropical forest system has been shown to be more resilient to climate change and can serve as a buffer to future changes in climate (Gumpenberger *et al.,* 2010; Zelazowski *et al.,* 2011; Huntingford, 2013). Some other studies have even found a positive impact on tropical forest due to climate change. For example the impact of climate change on net primary productivity (NPP in gC/m^2 y^{-1}) of Indian forests was estimated to be 835 gC/m^2 by Ravindranath *et al* (2006) under the current GHG scenarios and a doubling of NPP under the A2 GHG scenario, while the moderate B2 GHG scenario projects an increase of about 73% for the forested grids. NPP was projected to increase in all the forested grids mainly due to the CO_2 fertilization effect on forest ecosystems. Also a study by White *et al.* (1999) using the climate scenarios HadCM2 and HadCM3 for the period 1860-2100, predicted that vegetation carbon would increase by 290GtC between 1860-2100 (compared to 600-630 GtC for 1999). Works by Adams *et al.,* 1998; Steffen and Canadell (2005) have also demonstrated the positive impacts of carbon fertilization in the forest ecosystem.

Also the Ricardian model does not take into account these biophysical interactions in the forest system and most importantly the effect of carbon fertilization in the face of drought and increase in temperature (Adams *et al.,* 1998; Steffen and Canadell, 2005). These are factors which are very important for a better understanding of the impact of climate change in the forest system. These shortcomings could also be implicit on the limitations of the model; the Ricardian approach has been criticized for being a static model (Quiggin and Horowitz, 1999). Another concern with the model is that the results may not be robust over time and that the weather and economic factors in a given year may have distorted the results, or that one year's climatic data may not capture climate change impact in subsequent year. Nevertheless, Mendelsohn and Nordhaus (1999) assert that the static comparative structure of the Ricardian model is a useful first step and can serve as a building block for future dynamic analyses of impacts. These shortcomings in the model are evident in the

R^2 which shows that the variables in the analysis explain only about 11% in variation in net revenue of the households. Thus, the unexplained variation in the constant term is highly significant and accounts for as much as ₦417,809 ($2785) out of ₦507,024 ($3380) predicted by the model. This is not surprising as the analysis is based on socioeconomic dynamics of forest use and does not account for the biophysical interactions that bring about changes in the output of the forest; which is not within the scope of this analysis. Thus, there is a need for further investigation using an integrated framework (Matsuoka *et al.*, 2001; Hayhoe *et al.*, 2010; Wing and Lanzi, 2014) in these areas for a better understanding of the interactions of all these variables to bring about the resilience or vulnerability of tropical forest systems to global climate change. This can be done through a multidisciplinary research looking at the different aspects of the problem under a unified framework and objective.

Contribution of the Ricardian model in this analysis

One unique advantage of the Ricardian model above and over all other climate change models as is the case in this analysis is its ability to capture the value of the land (net revenue) as a product of the changes in climatic variables. According to Mendelsohn *et al.* (1994, 1999) and Liu *et al.* (2004), the value of the change in the environmental variables is captured exactly by the change in land values across different conditions. Spatially the linkage between climatic variables and net revenue (in cross-sectional observation) where normal climate and edaphic factors vary can hence be utilized to estimate farmer-adapted climate impacts on production and land value. In this regard crop net revenue has been found to be sensitive to seasonal precipitation and temperature as they have great impacts on production and land value (Mendelsohn *et al.*, 1994, Mendelsohn and Neumann, 1999; Dinar *et al*., 1998; Mendelsohn 2001; Mendelsohn and Dinar, 2003; Liu *et al.*, 2004; Seo *et al.*, 2005; Kurukulasuirya *et al.*, 2006; Seo and Mendelsohn, 2008d). so the value of the output of the land (net income / rent) is a reflection of the outcome of the interactions of the exogenous (climate and edaphic factors) on the system. This is because the different climatic variations across different regions introduce the required changes (as in temporal climate change situations), whose effects across zones reflect what the situation is likely to be under climate change situation. Thus, the variation in space mimics the temporal variation in climate.

Most importantly the Ricardian approach captures the adaptation that farmers make in response to local environmental conditions, that is the actual response by farmers (in the field, so long as they are responding to different conditions), rather than the controlled ones in the other models. It is for this reason that the model is not useful in locations where climatic conditions are the same in all regions. This is because it is these practical changes in response to changing conditions (climate change) that introduces the differences in net revenues of the different sampling units (farmers); differential rents. It therefore captures the farmers' choices over crop mix instead of yield (Liu *et al.*, 2004). By so doing it avoids the problem of the inherent bias "dumb-farmer scenario" (Mendelsohn *et al.*, 1994) associated with other models; they omit a variety of the adaptations that farmers customarily make in response to changing economic and environmental conditions as no changes are permitted to farming methods across experimental conditions, thus overestimating the damage. Thus, they do not, and indeed cannot, take into account the infinite variety of substitutions, adaptations, and old and new activities that may displace no-longer-advantageous activities as climate changes (Mendelsohn *et al.*, 1994).

Temporarily, the estimated parameters from the Ricardian model simulate climate change impacts based on a set of climate change scenarios which are used to make projections for the future. The projections are intended to provide a sense of the impact of climate change in the future (Seo and Mendelsohn, 2008a). In essence climate change is reflected in the model parameters via the spatial and temporal changes in the different variables, in the model and of course captured in the alterations in the socioeconomic conditions of the sample units as a result of their spontaneous adjustments (adaptation) to the changing climatic conditions, in their quest to build resilience. Thus, according to Wood and Mendelsohn (2014), each farmer is assumed to maximize net revenue given various exogenous constraints on his or her farm, such as climate, soils and socioeconomic conditions. Farmers will choose the particular crop, land use and inputs that maximize net revenue for their land.

Limitations of the study

One of the limitations of the study is the use of net revenue instead of land value in the analysis. This is a limitation as net revenues tend to reflect annual weather as it is difficult to estimate long term climate changes with annual revenue (Mendelsohn and Dinar, 2009). In the case of this analysis, net revenue is the most realistic approximation of land value, as in most cases land value are over estimated depending on their location (urban or rural) and therefore does not always reflect the actual value of the output of the land. Also since we are dealing with forest production, the outputs are so varied, spatially and temporally distributed in so many property right regimes that it is impossible to allocate any particular product(s) to any particular land unit.

Also the use of net revenue has been criticized for the problem of aggregation (Mendelsohn and Dinar, 2009), which is introduced because farm data that exist tend to aggregating annual yields over large terrains. In this analysis the problem was overcome by carrying out primary data collections which assigns prices to each specific sample unit in the analysis.

With respect to the survey design and data collections, it wasn't easy to achieve a perfect random sampling, due to financial and time limitations, since in some cases the required individuals were not on ground to be interviewed, refused to be interviewed or were indisposed and therefore has to be replaced with another person that is willing to participate. Nevertheless, efforts were made to get as much representative of the variations in the different ecological regions as possible that is required for the analysis. In addition variations in the understanding and interpretation of the concept of climate change from place to place, due to differences in language and literacy levels across zones; interviewers' and interviewees' bias were factors that may have play out in the analysis. Nevertheless efforts were made to harmonize such discrepancies by calling the respondents on their mobile numbers for clarifications in the cases of obvious deviations, before the analysis. Also the prior training of the research team, pretest of the questionnaire and constant monitoring and feedback from researchers while in the field were helpful in resolving some of these issues.

6.0 Conclusion and recommendation

Climate change will have diverse impacts on different sectors and regions depending on their prevailing circumstances; thus, the need for a better understanding of the interactions between global climate change and agricultural system. The results show that increase in rainfall has adverse effect on forest resource use during the summer and autumn seasons. This could be related to excessive rainfall, which limits both the logistics of accessing forest resources and damages to products during the period. On the other hand it is beneficial during the winter and spring seasons. Though there was a negative impact of a $1^{o}C$ increase in temperature on net revenue, this was very small and negligible to make any difference, which underscores the resilience of tropical forest ecology to climate change. This resilience is further re-enforced by the fact that further increase in temperature or decrease in rainfall does not show any significant change in net revenue. The source of this resilience of the agro forestry system as is the case in this study could no doubt be due to intrinsic adaptive capacity of the forest ecology, to adjust itself to adverse climate effects. Secondly, it could also be that impact has reached a plateau within the limit of available data and any further changes in the factors does not make any difference or due to the weakness of the model to track impacts due to biophysical changes. We therefore call for further integrated assessment for a better understanding of biophysical dynamics of interactions of tropical forest and current and predicted climate change. Nevertheless, the results offer useful insights to researchers, policy makers and development practitioners in their quest to understand the nature and magnitude of climate change impact in tropical forest systems, which is useful towards targeted policy interventions, especially in the areas of mitigation and adaptation planning in forest resource management.

Appendices

Appendix

Appendix 1: Average seasonal temperature in the different ecological zones (^oC)

Ecological zone	spring	Summer	Autumn	winter
Mangrove	32.34	29.23	30.42	32.82
Rainforest	31.77	28.61	29.80	32.32
Guinea Savanna	35.16	30.51	32.05	35.51
Montane	29.89	25.12	27.31	28.26
Sudan Savanna	37.92	32.87	33.51	30.63

Appendix 2: Average annual seasonal rainfall in the different ecological zones (cm)

Ecological zone	spring	Summer	Autumn	winter
Mangrove	175.02	319.01	232.84	40.98
Rainforest	222.98	419.94	285.13	34.44
Guinea Savanna	92.02	181.7	145.37	0.38
Montane	109.46	258.21	69.75	3.04
Sudan Savanna	21.43	164.38	37.05	0

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CHAPTER FIVE

Climate Change Perception and Adaptation in Nigeria

5.1 Preface

Production and activity within the agriculture, forestry and fisheries sector is inherently affected by climate variability; there is a tradition of perception and coping with year-to-year changes in climate. Understanding how individuals' experiences and attributes influence their understanding of climate change, and their consequent adaptation processes, is important to inform development targeted policies and appropriate interventions among the forest communities. Human-induced climate change is expected to require a greater rate and extent of adaptation than previously needed (Wheeler and Tiffin, 2009). These changes and their consequences give an indication of the vulnerability of our social, economic and environmental systems to the vagaries of nature and reveals the gap that exist in terms of adaptation, thus signalling the need for adaptation. If we are to manage the risks such as conflicts, migration and the associated health impacts posed by unavoidable climate change, adaptation is therefore inevitable (Adger and Barnett, 2009; Smith *et al.*, 2011).

There are basically two main outcomes of adaptation (*i*) reducing overall vulnerability to climate shocks (''adaptive strategies'') and (*ii*) managing their impacts *ex-post* (''coping strategies'') (IFAD, 2008). The distinction between these two categories is however frequently blurred (Davies, 1996): what start as coping strategies in exceptional years can become adaptations for households or whole communities (Morton, 2007). In the case of Nigeria there are many adaptation options used by different farmers and forest communities to ameliorate the impacts of climate change in forest systems. In the case of this study the following adaptation options were identified: agroforestry, erosion control, changing dates of operations, use of improved / energy cook stove, cultural practices, irrigation and migration. These adaptation options, if adequately designed and applied in response to specific local contexts and realities, can limit the negative effects of climate change and land degradation on livelihoods in Africa. Many of these adaptation measures are already familiar to the rural dwellers, but their effectiveness now depends on careful selection and application and enabling policy environment, so that they are implemented in the right place and at the right time.

This chapter has three sections. In section one the logit model was used to analyze the perceptions, awareness and adaptation decision of forest communities in Nigeria, showing how socioeconomic and climatic factors are associated with the individual perceptions of climate change and decisions to adapt presented in a paper titled 'Climate change perception, awareness and adaptation decision among forest communities in Nigeria', and has been submitted for publication to the Journal of Mitigation and Adaptation Strategies for Global Change. In section two the logit model was used to analyze the determinants of adaptation in Nigeria, showing the likelihoods of use of different adaptation strategies given the individuals' socioeconomic and agronomic attributes, as well as climatic factors. The work is presented in a paper titled; 'Determinants of adaptation strategies to climate change in Nigerian forest communities', and has been submitted for publication to the Journal of Regional Environmental Change. Section three presents findings on the benefit cost analysis of each of the adaptation strategies showing their levels of cost effectiveness. It also presents the barrier to adaptation strategies in Nigeria. This section is currently being written as a paper for publication.

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5.2 Climate change perception, awareness and adaptation decision among forest communities in Nigeria

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Abstract

Understanding how individuals' experiences and attributes influence their understanding of climate change, and their consequent adaptation processes is becoming increasingly important to development targeted policies and interventions among the forest poor. The perception of climate change and adaptation decision of forest communities across Nigeria were analyzed using the logit model. Results show that over 88% of the respondents have perceived climate change in one form or the other in all the ecological regions except in the montane forest where only 33% of the surveyed respondents had noticed climate change. Over 84 % are aware of changes in forest resource use over time except in the montane forest where only 24% did. Ability to notice climate change was positively associated with spring rainfall, but negatively associated with education, net income, summer and autumn precipitation. Decision to take up innovation was positively associated with access to electricity, number of years of forest use, winter rainfall and temperature, and negatively associated with summer rainfall. Spring rainfall has a 2.4% likelihood of positively influencing the chance of noticing climate change, while it is negative with summer and fall rainfall; 0.4 and 1.7% respectively. Access to electricity, number of years of forest use and winter rainfall likely increase innovation adoption by 18.6, 0.5 and 1.5% respectively, while summer precipitation reduces the likelihood of adoption by 0.4%. These information could be used to help build the adaptive capacity of forest communities, not only in Nigeria but across the developing world.

Keywords: Adaptive capacity, Adoption, Forest resources, Innovation, Policy

1.0 Introduction

Although climate change is perceived differently depending on socio economic variables, location and livelihood activity (Diggs, 1991; West *et al.*, 2007), farmers respond to climate stimuli (Bradshaw *et al.*, 2004; Belliveau *et al.*, 2006; Maddison, 2007; Nhemachena and Hassan, 2007). Experience in Africa suggests that, in addition to agronomic performance, farmers perceptions are often determinants of adoption (Wortman and Kirungu, 1999). When a new technology or practice offers genuine benefit to stakeholders, slow adoption rate can be a concern to policy makers, extension practitioners; especially when they have to put everything in place to facilitate effective adoption (Onyekuru, 2008). This situation no doubt arises when there is a divergence between the attributes of the innovation and those of the adopter.

Adaptation in its simplicity is how the perception of climate change translates into the decision-making process (Bryant *et al*., 2000) via different individuals and sectors. Their perception determines the course of action taken that is dependent on their different characteristics and the prevailing environmental conditions. Thus, in order to adapt to climate change, individuals must first perceive that changes are taking place (Madison, 2007; Asfaw and Lipper, 2011); subsequently their choices and farming practices are based on a set of expectations about weather and markets (Madison, 2007), as well as information they may obtain from a range of sources including extension agents. Asfaw and Lipper (2011) and Pannell (1999) point out that if farmers are to adopt land conservation techniques they must first be aware of the technology and perceive that it is profitable.

Environmental behaviors are more likely to occur when an individual believes there is a problem (Lubell *et al.,* 2007; Haden *et al.,* 2012) and understanding why farmers do what they do can improve the quality of policy and programming decisions at various levels (Leagans, 1979; Edwards-Jones and McGregor, 1994; Beilin *et al.,* 2012; Below *et al.,* 2012; Nicholas and Durham, 2012; Niles *et al.,* 2013). Thus, farmers who believe that climate change will add risk to their livelihoods are more likely to support and participate in policies that aim to address climate change. Thus, there is a need for a clear understanding of the circumstances under which adoption thrives, the perceptions and characteristics of the adopter and the nature of the environment and the attributes of the innovation itself (Onyekuru, 2008). Personal characteristics and economic conditions influence farmers' responses to climate change and variability – poor farmers are likely to take measures to ensure their survival, while wealthier farmers make decisions to maximize profits (Ziervogel *et al.,* 2005). Experience has shown that there are numerous examples of promising innovations that have not been taken up by farmers even when the need is obvious (Guerin, 1999; Onyekuru, 2008). There are several factors that influence this; adoption rate depends on several personal and socioeconomic characteristics (Tenge *et al*., 2004; De Graaff *et al*., 2008), that is the crux of this paper. Although there has been considerable research on farmers behavior, surprisingly there has been little empirical quantitative analysis on farmers' individual adaptation decisions, especially addressing the complex, forward-looking and site-specific characteristics of adaptation processes (Below *et al.,* 2012), or on how farmers' climate change beliefs impact on their plans for the future (Wheeler *et al.*, 2013). Because adaptation is often conceptualized as a site specific phenomenon, many authors call for local-level analysis to gain a better understanding of the fundamental processes underlying adaptation and for better targeting of adaptation policies by national and local, MGOs and bi-lateral donors (Smit and Wandel, 2006, Boko *et al*., 2007, Mano and Nhemachena, 2007). Hence the need to have a good understanding of conditions which influence perceptions and the adoption process. To ensure the design of sound policies that minimize unintended consequences, it is important to understand the influences underlying farmers intended strategic responses at the micro level; in particular how farmers' beliefs drive change (Wheeler *et al.,* 2013).

1.1 Theoretical framework

Farmers consider a variety of factors in deciding whether or not to adopt particular practices, these include various socio-economic, cultural and institutional, as well as biophysical and technical (McDonald and Brown, 2000; Soule *et al*., 2000), could be farmer-specific, farm specific and technology-specific (Lapar and Pandey, 1999). Farmer-specific factors include the broad goals of the farmer and the socio-economic milieu under which production takes place (Lapar and Pandey, 1999). Farm-specific factors are related to the biophysical characteristics of the production systems such as soil characteristics and interactions with prevailing climate, as well as the broader characteristics of the production system. Technology-specific factors are the attributes of the technology available to the farmer to assist in their production process. The choice will depend on three main aspects: firstly, the characteristics of the innovation themselves; secondly, the personal attitudes and preferences of the individual farmer and, thirdly, the farmers' conditions such as the financial situation, the specific climatic and regional site conditions or the general legal restrictions and policy settings (Sattler and Nagel, 2008).

Adaptation to climatic changes requires a combination of various individual responses at the farm-level that vary from household to households and region to region based on existing support systems and the resilience of affected individuals (Mengistu, 2011). Adoption was first measured by Rogers (1958) who used the time at which a practice was adopted as a classification criterion. Ervin and Ervin (1982) considered adoption a decision-making process and tried to include a wide range of personal, physical, institutional and economic factors into their classical conservation decision model. It considers three stages: (1) the perception of the problem, (2) the decision to use the practices and (3) the determination of outcome of effort. Even when farmers perceive the problem and are aware of possible solutions, they can decide not to use practices. Many different factors, known as the barriers to adoption, can lead to the non-acceptance of alternative.

To understand the driving forces behind human behaviour in relation to the adoption process, it is important to understand the rationale behind what motivates people to undertake action (Kessler, 2006). Deci and Ryan (1985) distinguish between intrinsic motivation (doing something because it is inherently interesting or enjoyable) and extrinsic motivation (doing something because a reward is expected). Intrinsic (or self-determined) motivation can promote sustained environmental behaviour (Osbaldiston and Sheldon, 2003), while extrinsic motivations provide less durable changes (De Young, 1996). Decision-making is also strongly influenced by non-rational and subjective aspects (Kessler, 2003). Individuals' feelings and aspirations require a favourable mental attitude (Leagans, 1979; Giampietro, 1997). Thus, the household's ability to adopt depends on a wide range of obvious socio-economic factors; willingness is often also influenced by strictly personal and behavioural factors (Kessler, 2006; Feder *et al*. 1985).

Though some individuals will never adopt practices, even if they are economically feasible, they may be regarded as ignorant or laggards (Kessler, 2006), but Vanclay and Lawrence (1994) argue that some aspects of individuals' resistance must be considered legitimate aspects of human behaviour, and not as deficiencies in their attitudes. In support of this view point, Pannel (1999) asserts that it can be constructive to recognize when slow adoption of a new technology may be the result of a rational wait for more high-quality information about its value to become readily available, rather than some intractable attitudinal or social barrier to change. Waiting for more information to reduce uncertainty (and the risk of making a costly wrong decision) can be of more economic value than early adoption; sometimes even when the individual already considers it more likely than not that the new innovation will be profitable (Dong and Saha, 1998). Thus, Llewellyn (2007) advocates for a closer attention to information-related factors about the innovation in adoption decision process.

For this study therefore, the theory of the association between adoption decision and exogenous variables of the farmers and the system are therefore relevant. We therefore hypothesize that there is a relationship, without necessarily causation, between the farmers' attributes and their perception and adoption decision processes.

2.0 Materials and methods

2.1 Sampling

Using a structured questionnaire, data were collected from 400 rural households, sampled from five broad ecological regions in Nigeria (Fig.1) to assess the socio economic attributes of respondents, how they have been impacted upon by climate change and what their perceptions of climate change and adaptation decision process are.

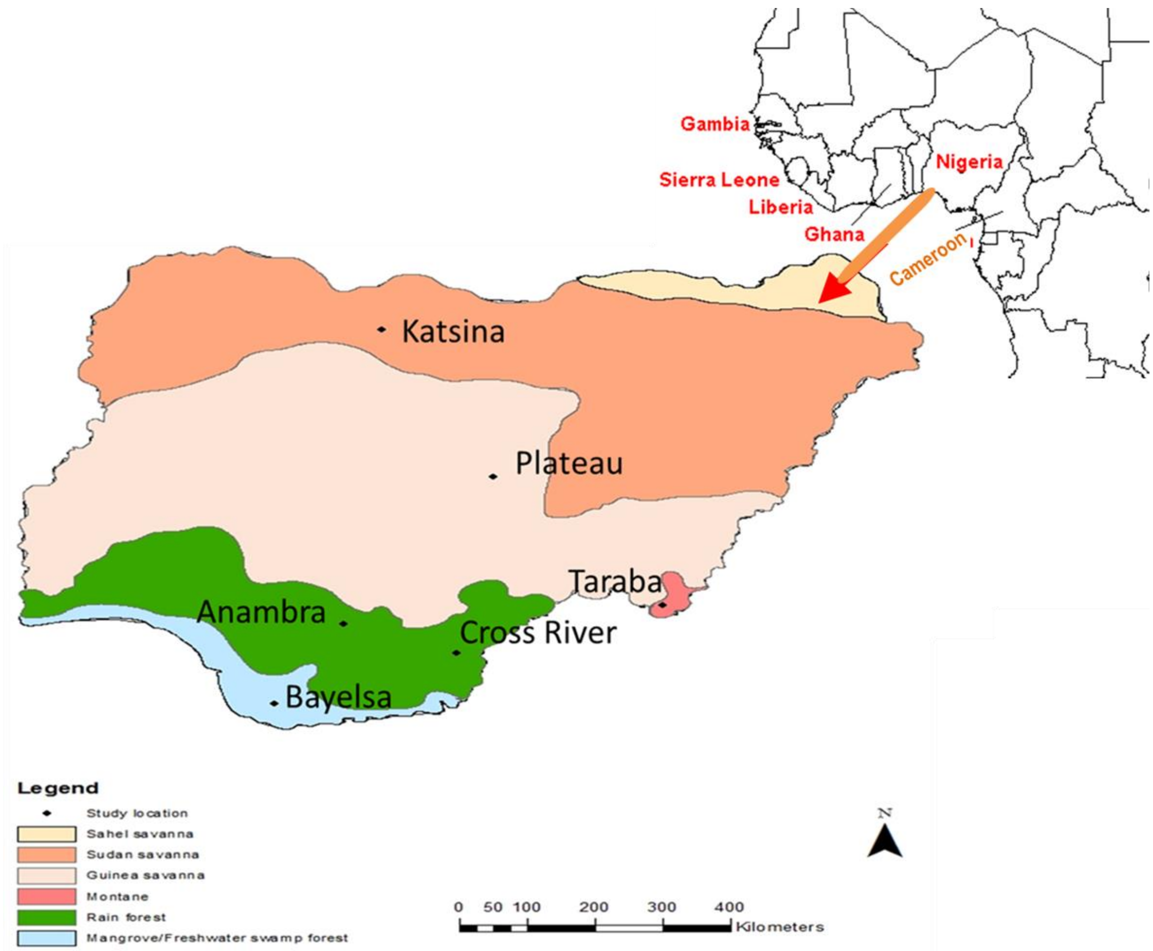


Figure 1. Agro ecological map of Nigeria showing locations where communities were assessed.

Based on the relative size of the population which they support, and the prevalence of forest cover, 150, 100, 100, 50 and 50 households were sampled from the rainforest, mangrove forest, Guinea Savanna, montane forest and Sudan savanna zones respectively (Figure 1). The consideration in the sample selection here was not necessarily to get a representative weighted sample, but to get sufficient sample across each zone for the analysis. For the rainforest zone the Cross River high forest was chosen as this is the only area of surviving lowland rainforest cover, not just in Nigeria, but across West Africa. Communities were selected from the respective states considering the availability of knowledgeable research assistants in the area who could understand the local languages. Communities were selected based on information from local informants on their reliance on forest resources. Five communities were selected from each of the rainforest and mangrove forest areas, four from Guinea Savanna, three from montane and two from Sudan savanna ecological region. Communities were chosen using a random draw from all possible communities in the target areas. In each community different households from the roll call were selected at random intervals until the required number of households per community was reached (this was directly proportional to the total population of the different communities). Structured questionnaires were administered on a one to one basis, with the household heads, or other knowledgeable members of the households, who were conversant with forest resource use by the household and the wider community. To check for interviewer bias and ensure data consistency and compatibility, the addresses and mobile phone numbers of each respondent were collected and information supplied by the interviewer randomly crosschecked in all zones. The data collected were coded and screened for consistency and analyzed using STATA.

2.2. Theoretical model

Due to the dichotomous nature of the dependent variables, a binomial logit model was used to explore associations between the socioeconomic and climatic attributes and climate change perception and adaptation decision, as was employed in the work of Mbaga-Semgalawe and Folmer (2000) in Tanzania. Logistic regression applies maximum likelihood estimation after transforming the dependent into a logit variable. In this way, logistic regression estimates the odds of a certain event (value) occurring, calculates changes in the log odds of the dependent, but not changes in the dependent itself. According to Garson (2011), logistic regression has many analogies to OLS regression: logit coefficients correspond to 'β' coefficients in the logistic regression equation, the standardized logit coefficients correspond to beta weights and a pseudo R^2 statistic is available to summarize the strength of the relationship. The Wald statistic is used to test the significance of individual independent variables. In the logit model the qualitative dependent variables assume discrete rather than continuous forms. Thus, dependent variable "Y" can take only two values one and zero, thus depicting a binary outcome. The logit model is thus specified as follows:

$Y^* = \sum x\beta + \varepsilon,\ \varepsilon \sim N(0, 1)$

If $y^* > 0,\ y = 1$

If $y^* < 0,\ y = 0$

The dependent variables in this estimation are defined to have two possible values: 1, denotes the perception of climate change and decision to adapt while '0' denotes non perception and not adapting in two separate equations. Each of the dependent variables may be related to: household size, gender, age, number of years of forest use, level of education and occupation of household head, household net income from the forest, individual observation of climatic change, distance to the market, access to extension services, electricity, temperature and rainfall. The sign and size of the association between the dependent variables and the explanatory variables could vary from negative to positive and 0 to 100% respectively depending on the nature of the explanatory variables, economic theory and prevailing environmental conditions.

The dependent variables in the empirical estimation are perception of climate change and decision to adapt, while the explanatory variables are household size, gender, age, number of years of forest use, level of education and occupation of household head, household net income from the forest, temperature, rainfall, individual observation of climatic change, distance to the market, access to extension services and electricity and climatic variables (annual temperature and rainfall).These variables has been carefully chosen based on literature from other related studies and from theory.

The explanatory variables were regressed against each of the adaptation options (dependent variables) to estimate how each of the explanatory variables influence climate change perception and the decision to adapt; the level and direction of association. Marginal effect analysis was performed to determine the likelihood (percent) of each explanatory variable influencing climate change perception and adoption decision.

3.0 Results

Results on climate change perception show that majority (88%) of the respondents have noticed climate change in one form or the other in all the zones with the highest occurrence in the Sudan savanna and the least in the montane forest where only 33% has noticed climate change impact (Figs 2).

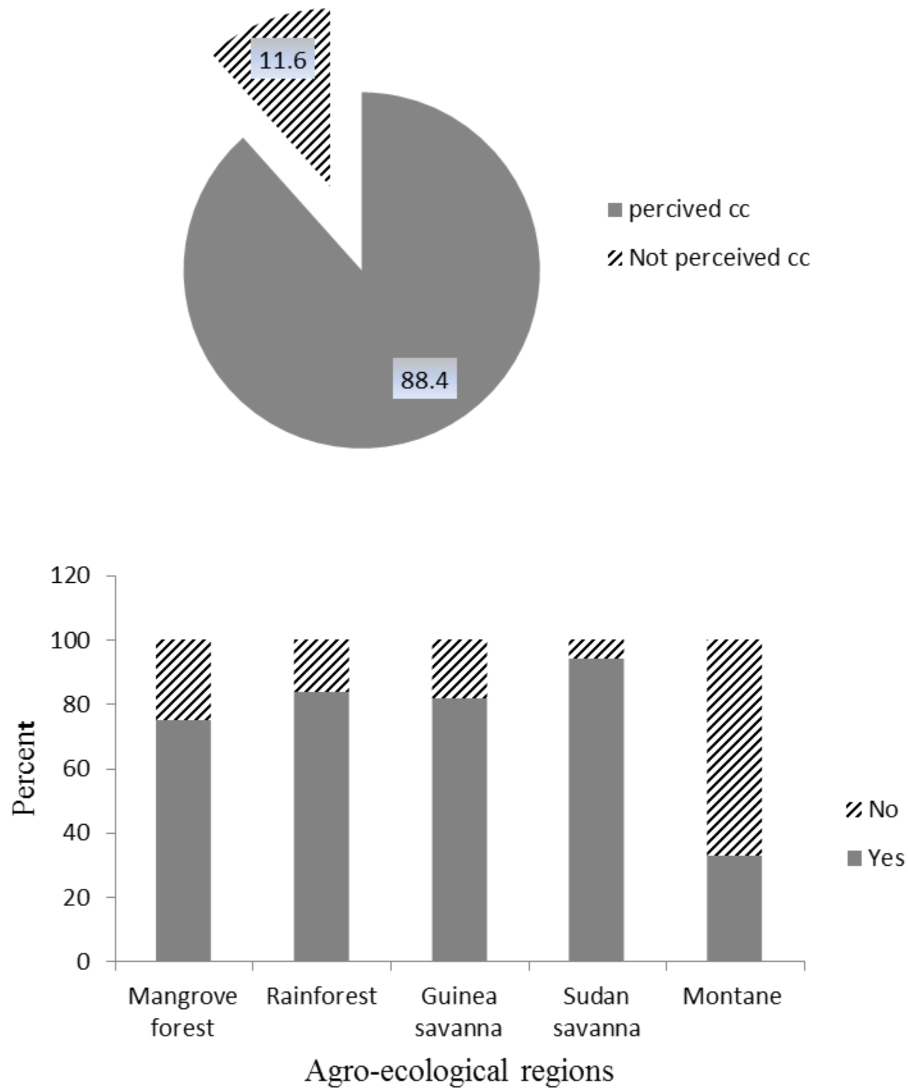


Figure 2. Climate change perception across the country (a) and in the different ecological zones (b)

While 84% of all the respondents have noticed changes in forest resource use (Fig. 3), 93% and 92% of the respondents in the rainforest and Guinea Savanna respectively have noticed changes in forest resource use due to climate change, while in the mangrove and Sudan savanna all the respondents noticed changes.

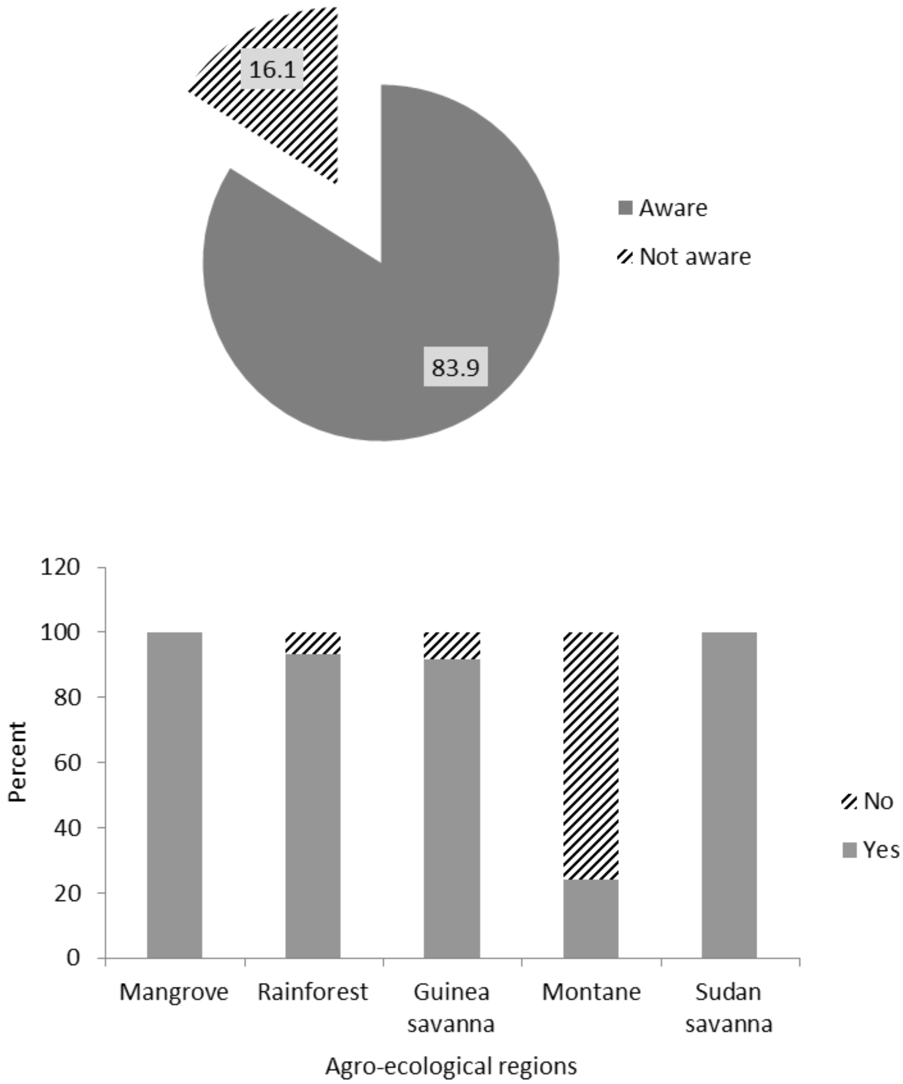
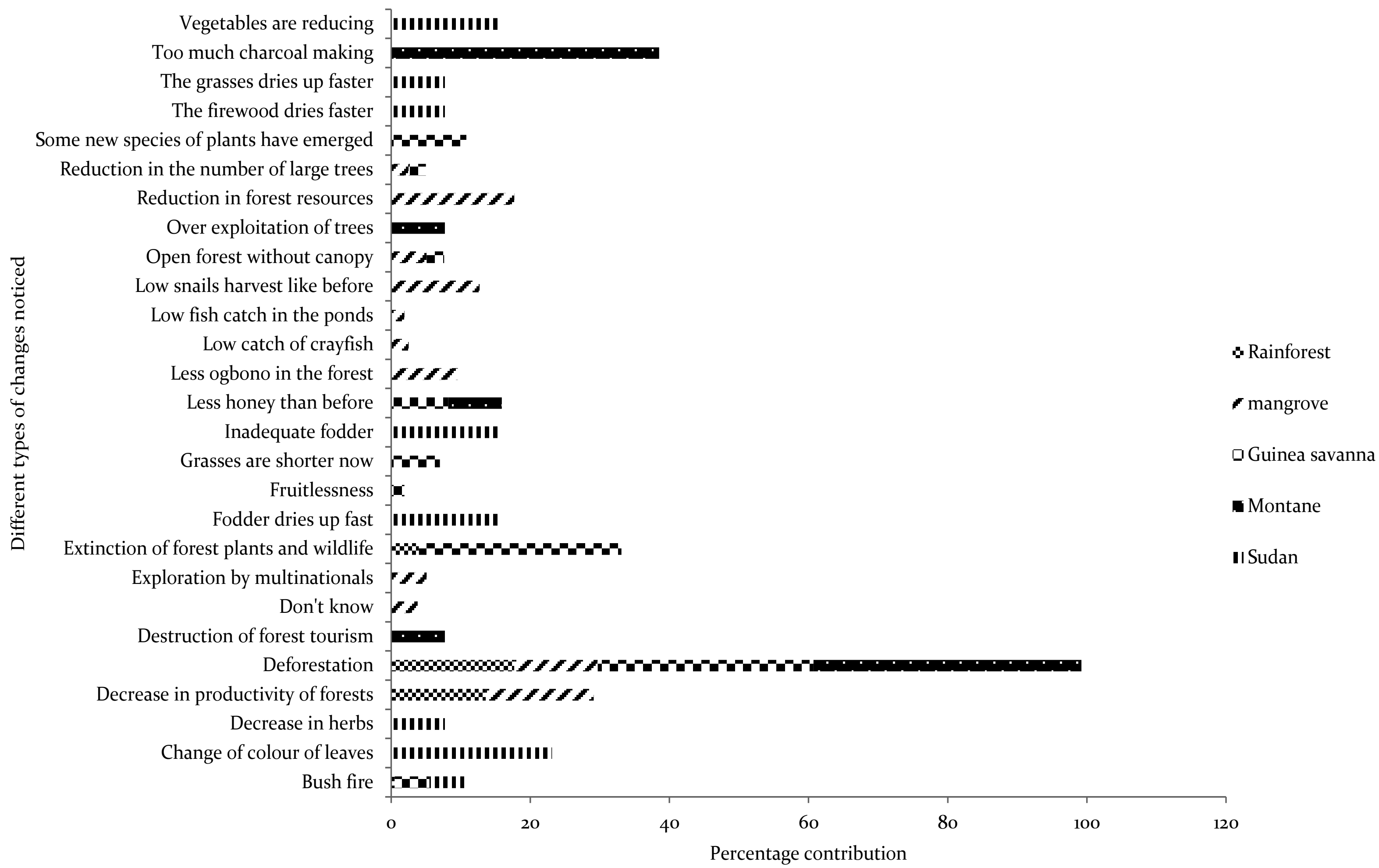


Figure 3. Level of Awareness of changes in forest resources due to climate change across the country (a) and in different ecological zones (b).

On the contrary, only 24% of respondents in the montane forest ecological zone affirmed that they have noticed changes.

With respect to specific changes noticed in the forest, several kinds of shifts have been reported (Fig. 4).


Vegetables are reducing
Too much charcoal making
The grasses dries up faster
The firewood dries faster
Some new species of plants have emerged
Reduction in the number of large trees
Reduction in forest resources
Over exploitation of trees
Open forest without canopy
Low snails harvest like before
Low fish catch in the ponds
Low catch of crayfish
Less ogbono in the forest
Less honey than before
Inadequate fodder
Grasses are shorter now
Fruitlessness
Fodder dries up fast
Extinction of forest plants and wildlife
Exploration by multinationals
Don't know
Destruction of forest tourism
Deforestation
Decrease in productivity of forests
Decrease in herbs
Change of colour of leaves
Bush fire
Different types of changes noticed
0
20
40
60
80
100
120
Percentage contribution
Rainforest
mangrove
Guinea savanna
Montane
Sudan

Fi

gure 4: Types of changes perceived in forest resource use in different agro ecological zones of Nigeria

In the Sudan savanna the major issue has to do with shortage of fodder, whereas in the montane forest and Guinea Savanna the problem has to do with reduction of forest cover which impacts on all other aspect of forest resources like honey output and fruit production. In the rainforest the major change experienced concerned excessive deforestation which impacts on forest productivity and loss of biodiversity. In the mangrove the changes experienced has to do with loss in different mangrove forest resources and the excessive pressure from multinational oil companies on the forest. In terms of perception of the extent of climate change impacts the phenomenon that are more prevalent are excessive rainfall, high temperature, dryness, loss of soil fertility and erratic pattern of rainfall (Table 1).

Table 1. Perceptions about the extent of climate change impact

Variables	N	Min.	Max.	Mean	S. D.
Thunder storms	26	1	5	2.65	1.2
Desertification	5	1	5	2.8	1.48
Heavy winds	41	1	5	3.1	1.39
Heat waves	32	1	5	3.16	1.14
No or reduced Harmattan	66	1	5	3.32	1.06
Uncertainties in the onset of farming season	62	1	5	3.36	1.20
Long period of Harmattan	66	1	5	3.38	1.27
Increase in pests problems	51	1	5	3.45	1.21
Less rainfall	25	1	5	3.48	1.42
Increase weed infestation	80	1	5	3.56	1.18
Delay in the onset of rain	104	1	5	3.64	1.15
Drying up of stream and rivers	6	3	5	3.66	0.82
Long period dry season	92	1	5	3.77	1.07
Drought	4	2	5	4	1.41
High rate of disease incidence	139	1	5	4.07	1.23
Loss of soil fertility	114	1	5	4.18	1
Early rains followed by dry spell	81	1	5	4.35	0.64
Heavy and long period of rainfall	78	1	5	4.36	1.08
Higher temperature	114	1	5	4.39	0.85
Erratic rainfall pattern	101	1	5	4.44	0.87
Overflowing of streams and rivers	10	3	5	4.5	0.71
Floods and erosion	97	2	5	4.54	0.78

Results of the logistic regression show that increase in the ability to notice climate change was positively associated with spring rainfall and negatively associated with education, net income, summer and autumn precipitation (Table 2). The decision to take up adaptation options was positively associated with access to electricity, number of years of forest use, winter rainfall and temperature, while it was negatively associated with summer rainfall.

Table 2. Summary of logistic regression analysis

	Notice of climate change		Adaptation decision	
Variables	Coef.	P>|z|	Coef.	P>|z|
Hhsize	.0519	0.429	0.0101	0.837
Gender	.6548	0.15	-0.2067	0.585
Age	.0100	0.501	0.0013	0.904
Level of education	-.0674	0.037	-0.0231	0.398
Access to electricity	.6149	0.244	1.2856	0.003
Primary occupation	-.0315	0.786	-0.1569	0.158
Years of forest use	-.0095	0.558	0.0365	0.011
Distance to market	.0102	0.137	0.0052	0.434
Transport mode to mkt	-.0512	0.907	-0.2587	0.441
Net revenue from forest	-0001	0.079	.0001	0.278
Extension visit	.0474	0.579	0.0251	0.623
Spring precipitation	.2726	0	0.0085	0.606
Summer precipitation	-.0421	0	-0.0282	0.004
Fall precipitation	-.1923	0	0.0106	0.35
Winter precipitation	.0495	0.156	0.1041	0.052
Winter temperature			0.1151	0.053
Constant	10.8979	0	1.9211	.
Chi^2	41.374	0	50.372	0

The marginal effect analysis (Table 3) shows that while increase in spring rainfall has a 2.4% likelihood of increasing the chance of noticing climate change, summer and fall precipitation have 0.4 and 1.7% likelihood of reducing the chance of noticing climate change.

Table 3. Marginal effects from the logit model

	Notice of climate change		Adaptation decision	
Variables	dy/dx	P>|z|	dy/dx	P>|z|
Household size	0.0046	0.453	0.0015	0.837
Gender	0.0576	0.225	-0.0300	0.584
Age	0.0008	0.519	0.0002	0.904
Level of education	-0.0059	0.133	-0.0034	0.395
Access to electricity	0.0541	0.304	0.1866	0.002
Primary occupation	-0.0028	0.788	-0.0237	0.155
Years of forest use	-0.0008	0.569	0.0052	0.009
Distance to market	0.0009	0.213	0.0008	0.432
Transport mode to mkt	-0.0045	0.907	-0.0376	0.441
Net revenue from forest	-0001	0.166	.0001	0.271
Extension visit	0.0042	0.591	0.0037	0.623
Spring precipitation	0.0240	0.025	0.0013	0.606
Summer precipitation	-0.0037	0.05	-0.0041	0.003
Fall precipitation	-0.0169	0.033	0.0015	0.346
Winter precipitation	0.0044	0.225	0.0151	0.05
Spring temperature			-0.0049	0
Summer temperature			-0.0065	0
Fall temperature			-0.0018	0
Winter temperature			0.0167	0.052

In the case of deciding to adopt adaptation strategies, increasing access to electricity, number of years of forest use and winter rainfall, all are likely to increase technological adoption by 18.6, 0.5 and 1.5% respectively, while increase in summer precipitation reduces the likelihood of adoption by 0.4%.

4.0 Discussion

The results on the perception of climate change resonates with those of other studies in different parts of Nigeria; Apata *et al. (*2009) in Western Nigeria, Idrisa *et al*. (2012) in part of northern Nigeria, Falaki *et al*. (2013) in North Central Nigeria, who found that local farmers have perceived climate change in different forms. Though there is low perception of desertification as an impact of climate change, probably due to the fact that the study was focused more on forested communities in northern Nigeria, so not many of the respondents leave closs to or have been affected by desertification. A study in 11 African countries by Madison (2007) indicates that significant numbers of farmers believed average temperatures had increased and rainfall levels had decreased with a change in the timing of the rains. Other similar findings are de Wit (2006) in 11 African countries, (Gbetibouo, 2008) in South Africa, Mertz *et al*. (2009) in Senegal, Jennings and Magrath (2009), Akponikpè *et al.* (2010) in Benin, Burkina Faso, Ghana, Advancing Capacity to Support Climate Change Adaptation (ACCCA) (2010) in Ethiopia, di Falco *et al.* (2011) in Ethiopia, Nyanga *et al.* (2011) in Zambia, Mandleni and Anim (2011) in South Africa, Mengistu (2011) in Ethiopia, Acquah-de Graft (2011) in Ghana, Kemausuor *et al.* (2011) in Ghana, Acquah-de Graft and Onumah (2011), Gandure *et al.* (2012) in South Africa, Habiba *et al.* (2012) in Bangladesh, Sahu and Mishra (2013) in India , Shankar *et al.* (2013) in India and African Technology Policy Studies Network, ATPS (2013) in Ethiopia All these studies indicate that between 70 to 98% of respondents affirmed that they have perceived climate change in different forms, thus, giving credence to our findings and underscore a global consensus about the level of awareness and agreement on the prevalence of climate change phenomenon. In essence, these local knowledge, perception and experience have helped to advance understanding of climate change and its impacts and is critical in guiding policy decisions and responses on adaptation, not just in Nigeria but across the globe. This in in line with the experiences of Salick and Byg (2009) in China, Tucker *et al*. (2010) in Central America and Mexico, Maddison (2007) in African countries, Bryan *et al*. (2009) in South Africa and Ethiopia and Kelkar *et al.* (2008) in India.

These finding are reinforced by the fact that a greater percentage of the respondents at least have an idea of what climate change is all about (Onyekuru and Marchant, 2014). It goes to show the high level of understanding of the concept of climate change phenomenon in Nigeria. So what is needed is a stakeholders synergy to take good advantage of this level of awareness to build on the understanding of the people about climate change to enforce positive behaviours with appropriate incentives; livelihood options, social capital, policies and programmes and even direct interventions. In this way the resilience and adaptive capacities of the rural poor can be enhanced for the greater benefit of the society and the ecosystem.

The negative association between level of education, level of income and climate change perception is not surprising as those with less education and most likely also have lower income are closer to the agro-forestry system than those with higher education and income as the former depend more on these natural resource base more than the later. So they are likely to be more conversant with any incidence of climate change and changes in forest resource use. Also since the less educated and lower income individuals are the ones that are more involved in forest resource collection, they were predominantly those sampled in the analysis and therefore the result will most likely tilt towards showing such signs. The educated are more engaged in other employment opportunities; cvil service and companies and less on the natural resource base system and their involvement in forest resource use are in most cases for leisure.

With respect to the factors influencing the likelihood of adoption, the result on the positive effect of the number of years of forest use (experience) resonates with those of Shortle and Miranowaski (1986), Gbetibouo (2008), Ayanwuyi *et al.* (2010), Dhaka *et al.* (2010), Baffoe-Asare (2013), Mudzonga (2012), Rana *et al.* (2012) and Shankar *et al.* (2013), who found that experience has a positive association with adoption decision. Thus, Ofuoku (2011) opine that those who have many years of farming experience have interacted much more with the climate in relation to their activities and therefore, have good knowledge of environmental factors as they relate to their daily operations. So they are more likely to be the first people to adopt innovation, having been convinced about the potential benefits.

It is not surprising that households with access to electricity are more likely to adapt to climate change than those that do not. Access to electricity in Nigeria is a sign of being well-off, better educated and to some extent wealthy, since the poor are frequently disconnected for failure to pay bills or are unable to connect due to cost. Thus they are more likely to be better informed and amenable to taking decisions to adapt to climate change than those without electricity access. This result agrees with that of Bryan *et al*. (2013) that those households with access to electricity in Kenya (an indicator of wealth) are more likely to adopt adaptation practices. More broadly Cinner *et al.* (2009) and Marshall *et al.* (2010) suggest that household access to electricity reinforces social and climate change resilience.

With respect to climate change perception, in the montane forest ecology as is shown in figure 2 and 3, perception and awareness is low relative to other regions due probably to the level of resilience of the tropical montane ecology from climatic shock as has been documented by Nadkarni and Solano (2002), Ching *et al.* (2011) and Onyekuru and Marchant (2014). That spring rainfall (late dry season and beginning of rainy season) favoured climate change perception is very unique. This is because the result tallies exactly with the situation on ground in Nigeria. During this period the dry season has peaked and in most cases is driest and hottest period of the year in different parts of the country (Leary *et al*., 2007) and as shown in table 3; showing the highest minimum and maximum temperature record in the year. Thus, it is therefore unusual to see heavy rains falling at this period of the year. So when suddenly it does, year after year for a long period of time, it then means that something is wrong. Such rains are very deceptive as they are followed by long periods of spell, such that those who ever tried to plant with the early rains get their crops scorched up. So, farmers have come to term with the fact that they have to wait till the rains are established and the soil is wet enough for them to plant. Thereafter, in the following months of June to November (summer and autumn), the results showed that they negatively influence climate change perception, as rainfall in these seasons are normal and are as expected. Except that sometimes they are heavier than normal with a lot of flood. This finding is reinforced by the result on the decision to adapt to climate change (Table 3), which also had a negative likelihood in the summer. In addition, too much rain during the summer inhibits forest activities by preventing access to the forest and other activities.

Winter rainfall (December – February) encourages the decision to adopt different adaptation strategies, this is a key finding vital in developing a Nigerian climate change adaptation framework. The continued existence of rainfall up to this period is encouraging farmers to plant some late crops, especially vegetables. Thus, in the absence of rain at this period some farmers who can afford it use irrigation. It is therefore very vital to target this period of the year by government and development practitioners to provide alternative sources of water for the farmers in order to empower them.

5.0 Conclusion

For effective design and implementation of any climate change adaptation policy, there is the need for adequate information and knowledge about the level of understanding of the people about the nature and extent of vulnerability, their perception of the level of risks they are exposed to, the different kinds of strategies in situ and the factors affecting their adaptation decisions. This study, like those of other scholars across Africa, shows a very high level of climate change perception and awareness in Nigeria. It indicates that though level of education and income inhibit climate change perception, on the contrary access to electricity and years of experience are valuable assets towards innovation adoption. Those that are economically well off are less likely to perceive climate change as they are less dependent on forest resources than those that are not. Furthermore, spring rainfall shift encourages climate change perception due to its unusual nature in recent times, while summer rainfall inhibits climate change perception and adaptation decision among the forest poor. There is therefore the need for stakeholders to synchronize these information for appropriate adaptation interventions at the right time with focus on the forest poor in order to build their resilience to climate change and their capacity to adapt.

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5.3 Determinants of adaptation strategies to climate change in Nigerian forest communities

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Abstract

The impacts of climate change are increasingly being felt by forest communities. Determinants of adaptation strategies were assessed across five broad ecological regions within Nigeria using a sample of 400 rural households from forest communities. The major adaptation strategies identified using bivariate logit model were agroforestry, erosion control, changed timing of operations, use of improved cook stoves, changed cultural practices, irrigation and migration. The determinants of adaptation strategies were level of education, mode of transportation (use of motorized vehicle) to access markets, detecting of climate change, household size, access to electricity, number of years of forest use, number of extension visits and net revenue made from the forest. Primary occupation (farming) and age of the household head were shown to be negatively associated with the adoption of different adaptation options. Seasonal rainfall and temperature were shown to impact on the use of different adaptation options. These findings could be used to incorporate adaptation strategies into national development planning to build resilience among forest communities in Nigeria, and the wider West African region.

Keywords: Agroforestry, Farmers, Logit model, Resilience, Vulnerability, West Africa.

1.1 Introduction

Although the nature of recent global climate changes is unprecedented, both in magnitude and impact, through geological history, local farmers and forest dwellers have traditionally survived and coped with climate shifts over time (Odero, 2011). In the tropics climate change is making weather less predictable, rains more uncertain and thunderstorms more likely (IPCC, 2014). Communities in West Africa have developed indigenous mechanisms and strategies over the years to cope with these changes (Nyong *et al*., 2007). Adaptation helps farmers achieve food, income and livelihood security in the face of changing climatic and socioeconomic conditions, including climate variability, extreme weather conditions such as droughts, floods and volatile short-term changes in local and large-scale markets (Kandlinkar and Risbey, 2000; Hassan and Nhemachena, 2008).

Farmers choose the levels of inputs, the kind of management, the desired number of animals/crops, management strategies and the species that will yield the highest net profit subject to exogenous socio-economic and environmental factors (Seo and Mendelsohn, 2008), sometimes reducing the negative impacts of climate change on crop yields by up to 50% (Reilly *et al*., 1996). With the increasing frequency and magnitude of climate change, it has become critical to understand how local people perceive and are adapting to these changes, and what factors influence their adoption of different strategies. Such information may enable practitioners, policy makers and individuals to better make informed decisions, and design incentives and policies that help to build resilience and enhance adaptive capacity against impacts of climate change (Hassan and Nhemachena, 2008; Seo and Mendelsohn, 2008). Increasing system resilience is directly related to increasing the adaptive capacity of farmers (Verchot *et al*., 2007) and an effective adaptation policy must be built on a wide variety of economic, social, political and environmental information (Spittlehouse and Stewart, 2003).

Theoretical Framework

Adapting to climate change is a human response to actual or expected climatic stimuli or their effects, which moderates harm or exploit beneficial opportunities and includes all activities that help people and ecosystems reduce their vulnerability to the impact of climate change (IPCC, 2007). Four response options have been identified as key: adaptation, mitigation, technological and financial (Global Leadership for Climate Action, 2009). While the last three can be subsumed into mitigation, and include options aimed at reducing greenhouse gas emission (renewable energy) or carbon storage (afforestation, as in REDD+), adaptation is aimed at coping or managing climate change impacts. The concept of adaptation is not a new concept, but has been advocated for as far back as two centuries ago; Ricardo (1817) suggested that the improvements which increase the productive powers of the land, such as the more skillful rotation of crops, or the better choice of manure, which are improvements (management) that absolutely enable us to obtain the same produce from a smaller quantity of land. It follows that given the climate, the farmer chooses the most profitable species, ensuring management regime and also the inputs that will maximize the value of the farmers' return. In other word, the driver of the action or inaction of the individuals' response to external shock is the quest to maximize profit or benefit. In this regard people pursue a range of livelihood outcomes by which they hope to improve or increase their livelihood assets and to reduce their vulnerability; five types of assets has been identified in the DFID sustainable livelihood framework that form the core of livelihood resources range from financial, human, natural, physical, to social capital, and by recent extension political capital (DFID, 2008). These forms of asset form the bedrock of any form of adaptation which the individuals strive to maximize in the way of adaptation. Adaptation strategies can be those that have evolved to (*i*) reduce overall vulnerability to climate shocks ('adaptive strategies'), and (*ii*) to manage their impacts *ex-post* ('coping strategies') (Morton, 2007). The distinction between these two categories is however frequently blurred (Davis, 1996): what start as coping strategies in exceptional years can become adaptations for households or whole communities. Adaptation is the most practical and pro-poor option, especially among developing countries with insignificant emission histories and therefore no immediate obligation to cut greenhouse gas emissions. In addition, such countries often have a natural resource base that is already being impacted upon by climate change and therefore have the need for immediate adaptation.

Different models have been used to analyze the determinants of climate change adaptation strategies on crop (Deressa *et al.,* 2009; Kurukulasuriya and Mendelsohn, 2008; Hassan and Nhemachena, 2008) and livestock (Seo and Mendelsohn, 2008) production. Farmers' adaptation to climate change in Nigeria have also been estimated (Enete *et al.*, 2011; Nzeadibe *et al.*, 2011; Sofoluwe *et al.,* 2011; Ibrahim *et al.,* 2011; Ajao and Ogunniyi, 2011; Okereke, 2012), although all of these studies have been localized in either a single state or one of the six agro ecological regions of Nigeria; with no single common national assessment. In this study, the logit model was used to determine the factors (socio economic, agronomic and climatic) that influence the use of different climate change adaption strategies among forest communities in Nigeria.

2.0 Materials and methods

2.1 Sampling

Data were collected from 450 rural households, sampled from five broad ecological regions in Nigeria (Fig.1). Using a structured questionnaire, interviews focused on assessing the socio economic attributes of respondents, how they have been impacted upon by climate change and what their adaptation strategies are. Based on the relative size of the population which they support, and the prevalence of forest cover, 150, 100, 100, 50 and 50 households were sampled from the rainforest, mangrove forest, Guinea Savanna, montane forest and Sudan savanna zones respectively (Figure 1).

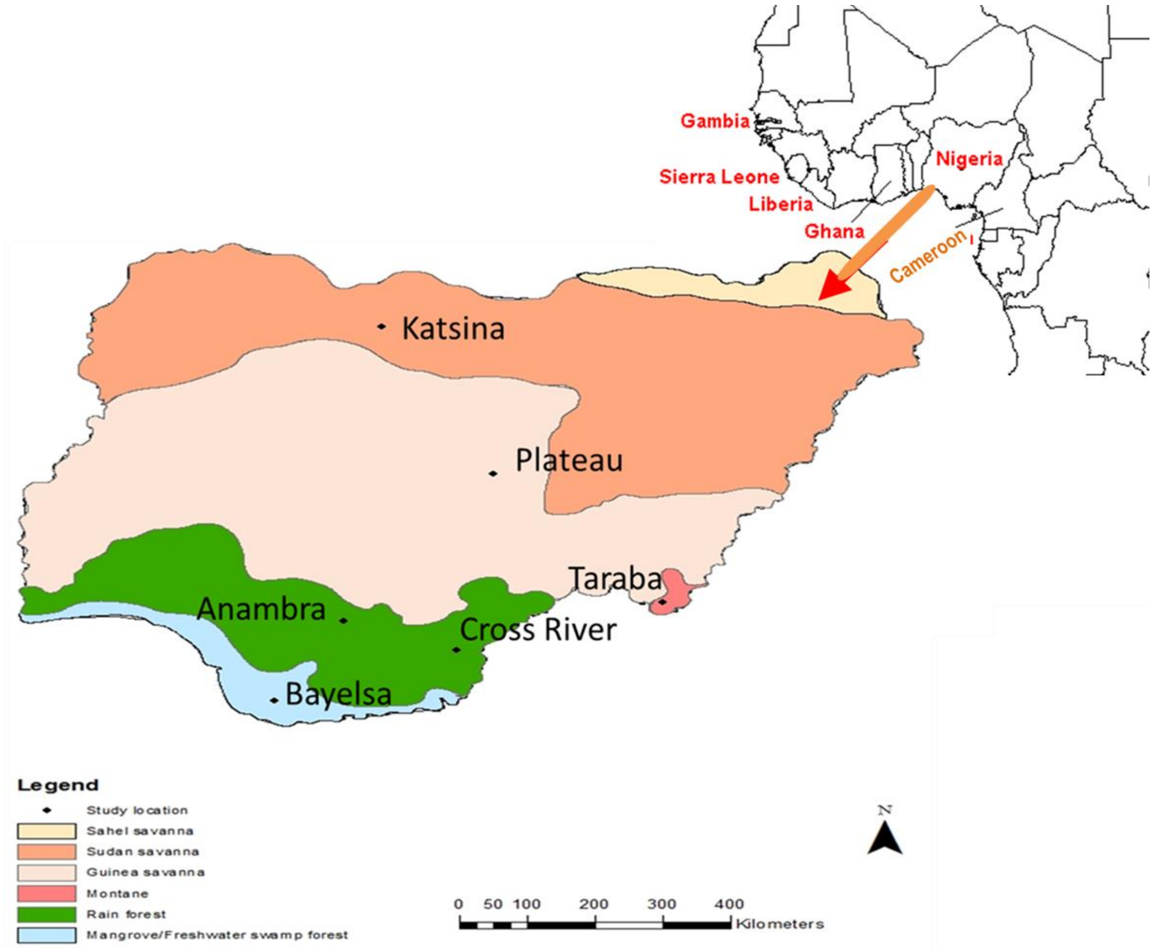

Figure 1. Agro ecological map of Nigeria showing locations where communities were assessed.

The consideration in the sample selection here was not necessarily to get a representative weighted sample, but to get sufficient sample across each zone for the analysis. For the rainforest zone the Cross River high forest was chosen as this is the only area of surviving lowland rainforest cover, not just in Nigeria, but across West Africa. Communities were selected from the respective states and knowledgeable research assistants in the areas who could understand the local languages were used for the data collection. Communities were selected based on information from local informants on their reliance on forest resources. Five communities were selected from each of the rainforest and mangrove forest areas, four from Guinea Savanna, three from montane and two from Sudan savanna ecological region. Communities were chosen using a random draw from all possible communities in the target areas. In each community households were randomly selected using the communities' roll calls; different households from the roll call were selected at random intervals until the required number of households per community was reached (this was directly proportional to the total population of the different communities). Structured questionnaires were administered on a one to one basis to the household heads, or other members of the households knowledgeable on forest resource use by the household and for the wider community. To check for interviewer bias, and ensure data consistency and compatibility, the addresses and mobile phone numbers of each respondent was collected and information supplied by the interviewer randomly crosschecked in all zones. The data collected were coded and screened for consistency and analyzed using STATA statistical software.

2.2. Theoretical model

In this study, due to the dichotomous nature of the dependent variables, a binomial logit model was used to explore associations between the socioeconomic and climatic attributes and climate change adaptation strategies as was employed by Silvestri *et al.* (2012), Bubeck *et al.* (2013), Panda *et al.* (2013) and Wood *et al.* (2014). Logistic regression applies maximum likelihood estimation after transforming the dependent into a logit variable. In this way, logistic regression estimates the odds of a certain event (value) occurring, calculates changes in the log odds of the dependent, but not changes in the dependent itself. The choice of the logit model for the individual adaptation options as against one single model, like Multinomial Logit Model (MNL), was due to the large number of factorial combinations which would be hard to analyze within one empirical model; as there were several simultaneous adaptation options reported by the respondents. This problem was also encountered by Silvestri *et al.* (2012), thus they opted for logit model. This is because the MNL model requires that the adaptation options be strictly mutually exclusive which in reality is difficult to achieve in the traditional African agricultural systems. Thus, in this analysis each adaptation option is treated as a single equation with binary outcome (1 for use and 0 for non-use). The logistic regression has many analogies to OLS regression: logit coefficients correspond to 'β' coefficients in the logistic regression equation, the standardized logit coefficients correspond to beta weights and a pseudo R^2 statistic is available to summarize the strength of the relationship. Goodness-of-fit tests such as the likelihood ratio test are available as indicators of model appropriateness, the Wald statistic is used to test the significance of individual independent variables. In the logit model the qualitative dependent variables assume discrete rather than continuous forms. Thus, dependent variable "Y" can lake only two values one and zero, thus depicting a binary outcome. The logit model is thus specified as follows:

$Y^* = \sum x\beta + \varepsilon,\ \varepsilon \sim N(0, 1)$

If $y^* > 0$, $y = 1$

If $y^* < 0$, $y = 0$

2.2.1 Definition of the variables

The dependent variables in this estimation are defined to have two possible values: 1, denotes the use of the adaptation option and 0 for non-use. The type of adaptation option used may be related to: household size; gender; age; number of years of forest use; level of education; occupation of household head; household net income from the forest; temperature; rainfall; individual observation of climatic change; distance to the market; access to extension services and electricity (Table 1). The sign and size of the association between each adaptation option and the explanatory variables could vary from negative to positive and 0 to 100% respectively (Table 1), depending on the nature of the explanatory variables, economic theory and prevailing environmental conditions.

2.2.2 Application of the model

In Nigeria most of the practices reported by researchers as adaptation options are actually agronomic practices driven by economic, traditional/cultural concerns and not necessarily specifically adapting to climate change. To address this issue, respondents were asked to state *the actual adaptation practices used specifically to cope with perceived impacts of climate change*, aside from their usual agronomic practices. Several adaptations options were reported, but were aggregated to merge similar options or those with same / similar outcomes, resulting in the following broad categories:

- Agroforestry
- Erosion control
- Changing dates of operations
- Use of improved / energy saving cook stove
- Cultural practices
- Irrigation/Drainage/use of wetland
- Migration

Thus, options like agroforestry includes water shade management, tree planting in different forms and reduction of tree cutting, while crops are integrated into existing trees. Irrigation includes all forms of water saving and supply, ranging from use of local drip irrigation, water harvesting, use of wetland, water channeling to more sophisticated drip irrigation. While cultural practices includes pruning, mulching, increased weeding, increased use of fertilizer/chemicals, use of resistant varieties and building of shades.

2.3 Analytical procedure

For this study, the dependent variable in the empirical estimation of adaptation options or response probabilities are seven as described above. The is the choice of an adaptation option from the set of adaptation measures listed above. The explanatory variables for this study are household size, gender, age, number of years of forest use, level of education and occupation of household head, household net income from the forest, temperature, rainfall, individual observation of climatic change, distance to the market, access to extension services and electricity and climatic variables; temperature and rainfall (Table 1).

Table 1. Description of variables used in the logit model analysis

Variable	Definition	Values/measure	Expected sign
Temperature	Winter, spring, summer and autumn temperature	^{o}C	±
Precipitation	Amount of rainfall in the winter, spring, summer and autumn seasons	mm	±
Noticed climate Change	Noticed changes in climate	1 = yes and 0 = no	±
Gender	Sex of household head	1 = male and 0 = female	±
Household size	Size of household	Number of members	+
Head age	Age of household head	Number of years	±
Experience	Number of years of forest use	Number of year	+
Level edu	Level of education of household head	Years	+
Majorocu	Major occupation	1 = farmer, 0 = others	±
Income	Net household income from the forest	₦	+
Distance	Time taken to get to the market	minutes	-
Extension	Access to extension services	Number of visits	+
Electricity	Access to electricity	1 = yes and 0 = no	+

These variables has been selected based on economic theory and literature from other studies as in Adesina *et al.* (2000); Ekwe and Onunka (2006); Nhemachena and Hassan (2007); Hassan and Nhemachena (2008); Deressa *et al.* (2009); Debalke (2011); Deressa *et al*. (2011); Negash (2011);

Cassidy and Barnes (2012); Mukasa *et al.* (2012); Rana *et al.* (2012); Tesso *et al.*, (2012); Fatuase and Ajibefun (2013); Baffoe-Asare *et al.* (2013), *inter alia*. In this analysis the explanatory variables were regressed against each of the adaptation options (dependent variables) to estimate how each of the explanatory variables influence adaptation to climate change; the level and direction of association. Furthermore, the marginal effect analysis was performed to determine the likelihood (percent) of each explanatory variable influencing the use of each of the adaptation strategies.

3.0 Results

3.1 Socioeconomic characteristics of the households

At the end of data screening, 50 questionnaires from the different regions were discarded for having incomplete information with a total of 400 used for the analysis. Most (53%) respondents have used the forest for between 11 and 20 years (Appendix 2) indicating that they have good understanding of changes occurring in their forests and thus could provide up to date account of climate change impact and adaptation information as required. Over 88% have detected climate change in one form or the other. The adaptation options identified to be of importance by the forest communities were different cultural practices (76%), agroforestry (66%), erosion control (52%), changing time of operation (46%), energy cook stove (10.6%), migration (8.3%) and irrigation (24%) (Fig. 2).

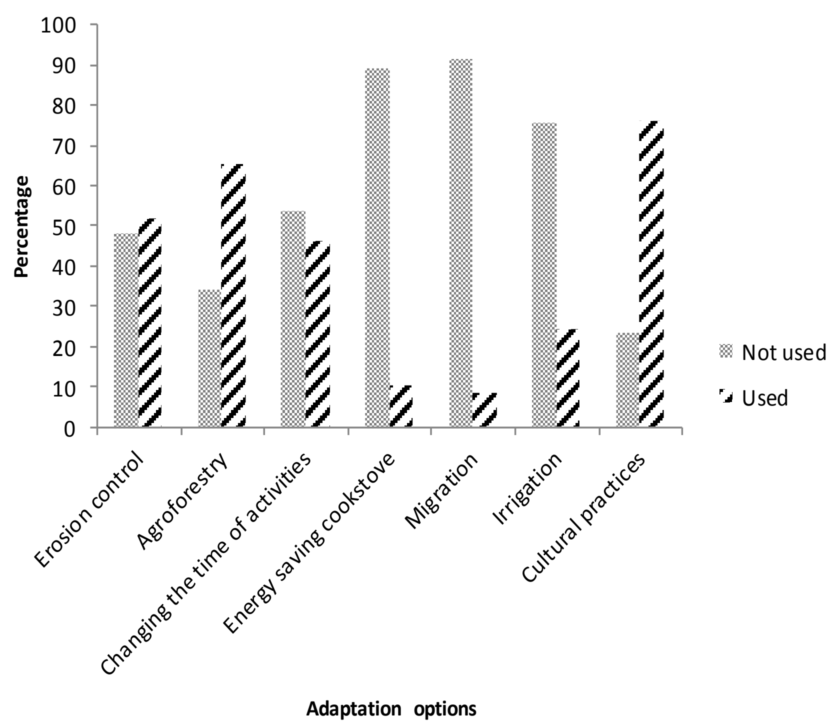

Figure 2. Adaptation strategies identified and their levels of importance

The majority of household heads involved in forest resource use and management were between the ages of 40 and 60, over 70% were male and majority (46%) only went to primary school only (Tables 2 and appendix 1 and 2).

Table 2: Descriptive statistics of explanatory variables used in the logit analysis.

Variables	N	Min	Max	Mean	S.D.
Household size	400	1	9	4.21	2.551
Gender of Household head	400	0	1	0.73	0.443
Age of household head	400	8	86	48.55	13.981
Level of education of household head	400	0	25	9.39	5.27
Access to electricity	400	0	1	0.59	0.49
Primary occupation	400	0	10	0.75	1.05
Number of years of forest use	400	1	60	19.9	10.73
Distance to the input market (minutes)	400	5	90	39.58	22.75
Mode of transportation to the market	400	0	1	0.66	0.48
Net revenue from forest products	400	5000	5500000	307893	532373
Number of visits from extension officers	400	0	24	0.51	2.65
Notice if climate change by the farmer	400	0	1	0.88	0.32
Spring precipitation	400	21.43	222.98	138.97	67.23
Summer precipitation	400	164.38	419.94	283.21	97.59
Fall precipitation	400	37.05	285.13	179.45	88.75
Winter precipitation	400	0	40.98	19.30	18.55
Spring temperature	400	29.89	37.92	33.30	2.41
Summer temperature	400	25.12	32.87	29.34	2.06
Fall temperature	400	27.31	33.51	30.68	1.76
Winter temperature	400	28.26	35.51	32.53	2.23

The predominant family size was between 3 and 6, the majority net income from the forest (34%) was between 51,000 ($320) and 100,000 Naira ($625), the average income from the forest was over 300,000 Naira ($2000)$yr^{-1}$. This income is often in combination with other activities like agriculture (64%) and artisan jobs. About 59% of the households have access to electricity, 53% have used the forest for between 11 and 20 years, about 50% take between 30 to 60 minutes to get to their markets and over 65% use motorized transport to go to the market, while about 95% of them have no access to extension agents (Appendix 2).

3.2 Determinants of adaptation strategies

The forest communities are engaged in several adaptive activities in response to the negative impacts of climate change. Depending on the socioeconomic and prevailing environmental attributes, their likelihood of using different adaptation options was either positive or negative (Tables 3 and 4).

Table 3. Summary of logistic regression analysis

Variables	Adaptation options													
	Agroforestry		Erosion control		Changing of time of activities		Use of improved cook stove		migration		irrigation		Cultural practices	
	coef.	Sig.	coef.	Sig.	coef.	Sig.	coef	Sig.	coef.	Sig.	coef.	Sig.	coef.	Sig.
Spring prec.	-0.023	0.222	0.067	0.888	-0.022	0.028	0.437	0.998	0.008	1	-0.076	0.8841	0.023	0.282
Summer prec.	0.003	0.733	-0.033	0.001	0.004	0.08	-0.474	0.996	-0.05	1	-0.122	0.008	-0.01	0.039
Fall prec.	-0.018	0.117	0.002	0.853	0.011	0.215	0.142	0.999	0.183	0.999	0.173	0.034	-0.001	0.922
Winter prec.	0.149	0	-0.023	0.464	0.006	0.81	-0.043	1	-0.999	0.997	-0.133	0.998	0.011	0.793
Spring temp.	-2.547	0.057	1.089	0.414	-0.454	0.692	-47.506	0.995	-1.929	1	-0.48	1	-3.929	0.023
Summer temp.	-2.189	0.261	3.493	0.068	0.191	0.908	-74.328	0.996	-19.762	0.999	13.02	0.998	-4.479	0.058
Fall temp.	6.87	0.109	-6.327	0.136	0.635	0.862	158.96	0.996	2.700	0.999	17.67	0.997	10.96	0.041
Winter temp.	-1.005	0.025	1.216	0	-0.19	0.614	-11.463	0.997	0.389	1	5.199	0.995	-0.873	0.1
Hhold size	-0.017	0.734	0.08	0.1	-0.055	0.214	-0.103	0.269	-0.017	0.853	-0.037	0.573	0.035	0.472
Gender	-0.019	0.952	-0.415	0.196	0.211	0.453	-0.052	0.919	17.433	0.995	0.07	0.832	-0.294	0.419
Age of hh head	-0.007	0.466	0.019	0.066	-0.027	0.003	-0.021	0.037	-0.061	0.083	0.032	0.011	0.01	0.323
Level of edu	0.043	0.1	0.051	0.042	-0.027	0.231	0.033	0.461	-0.071	0.148	-0.013	0.668	0.008	0.76
Has electricity	-1.255	0.004	0.958	0.032	-0.14	0.694	0.285	0.767	-14.673	0.994	1.906	0	0.45	0.254
Pri. Occupation	-0.41	0.094	-0.065	0.562	-0.068	0.537	0.047	0.759	-0.084	0.554	0.106	0.435	-0.059	0.581
Forest use yrs	-0.011	0.338	0.002	0.89	0.026	0.02	-0.058	0.005	-0.001	0.979	0.008	0.537	0.025	0.1
Distance to mkt	0.007	0.207	0.003	0.562	-0.003	0.584	0.024	0.008	-0.01	0.253	-0.001	0.822	-0.003	0.637
Mode of trans.	1.029	0.004	-1.278	0	1.028	0	1.051	0.107	2.421	0.027	-0.369	0.284	-0.533	0.121
Net rev (forest)	0	0.961	0	0.452	0	0.458	0	0.062	0	0.927	0	0.834	0	0.69
Extension visit	-0.138	0.205	0.061	0.414	-0.092	0.1	-12.349	0.993	-12.987	0.993	-0.054	0.241	0.059	0.433
Notice climate chan	2.823	0	-0.24	0.523	0.961	0.01	19.247	0.997	-4.90	0.937	0.433	0.346	0.484	0.208
Constant	-31.99	0.053	14.65	0.366	-4.022	0.775	-770.20	0.995	-236.38	0.999	-1.747	1	-45.44	0.03
Chi-square	46.71	0	128.7	0	96.15	0	114.45	0	127.5	0	118.9	0	48.34	0

Table 4. Marginal effects from the logit climate change adaptation model

Variables	Agroforestry		Erosion control		Changing time of activities		Use of improved cookstove	
	dy/dx	P>|z|	dy/dx	P>|z|	dy/dx	P>|z|	dy/dx	P>|z|
Household size	-0.003	0.731	0.014	0.095	-0.012	0.198	-0.151	0.050
Gender	-0.003	0.951	-0.073	0.185	0.047	0.441	-0.008	0.881
Age	-0.001	0.463	0.003	0.091	-0.006	0.003	-0.405	0.030
Level of education	0.008	0.082	0.009	0.031	-0.006	0.221	-0.063	0.509
Access to electricity	-0.222	0.005	0.170	0.035	-0.031	0.705	0.031	0.681
Primary occupation	-0.073	0.050	-0.011	0.521	-0.015	0.526	0.004	0.733
Years of forest use	-0.002	0.334	0.000	0.893	0.006	0.022	-0.107	0.026
Distance to market	0.001	0.211	0.001	0.551	-0.001	0.576	0.279	0.003
Transport mode to mkt	0.182	0.003	-0.226	0	0.227	0	0.113	0.114
Net revenue from forest	0.000	0.961	3.290	0.383	-3.820	0.436	-0.064	0.089
Extension visit	-0.025	0.008	0.011	0.309	-0.020	0.084	omitted	
Spring precipitation	0.500	0	-0.043	0.481	0.212	0.006	omitted	
Summer precipitation	-0.007	0.003	0.001	0.604	-0.004	0.131	-1.943	0
Fall precipitation	0.002	0.064	-0.003	0.009	0.001	0.257	-2.091	0
Winter precipitation	0.001	0.536	0.005	0.001	0.001	0.503	0.717	0
Level of education	0.012	0.012	-0.007	0.127	0.004	0.380	0.521	0
Spring temperature	0.008	0	-0.006	0	0.006	0	1.091	0.261
Summer temperature	0.014	0	-0.006	0	0.010	0	1.447	0
Fall temperature	0.004	0	-0.004	0	0.003	0	1.187	0
Winter temperature	-0.019	0.007	0.011	0.098	-0.012	0.108	1.504	0

Table 4. Marginal effects from the logit climate change adaptation model (continued)

Variables	Migration		Irrigation		Cultural Practices	
	dy/dx	P>|z|	dy/dx	P>|z|	dy/dx	P>|z|
Household size	-0.003	0.850	-0.067	0.461	0.006	0.469
Sex	(omitted)		-0.012	0.808	-0.047	0.412
Age	-0.0120	0.035	0.580	0.004	0.002	0.333
Level of education	-0.0140	0.115	0.082	0.516	0.001	0.761
Access to electricity	(omitted)		0.351	0	0.072	0.243
Primary occupation	-0.016	0.492	0.029	0.248	-0.009	0.596
Years of forest use	-0.000	0.982	-0.036	0.619	0.004	0.123
Distance to market	-0.002	0.285	-0.165	0.025	-0.001	0.638
Transport mode to mkt	0.458	0.027	-0.097	0.075	-0.085	0.116
Net revenue from forest	-0.000	0.891	0.033	0.494	0.000	0.625
Extension visit	(omitted)		-0.008	0.243	0.009	0.335
Spring precipitation	-0.009	0.934	0.077	0.318	0.077	0.194
Summer precipitation	0.000	0	-0.402	0	0.002	0.321
Fall precipitation	0.000	0.913	-1.036	0.015	-0.003	0.013
Winter precipitation	0.000	0	2.508	0	-0.000	0.964
Level of education	0.101	0	-0.141	0.301	0.010	0.059
Spring temperature	0.001	0	-0.511	0	-0.005	0
Summer temperature	0.001	0	0.003	0	-0.007	0
Fall temperature	0.001	0	-0.405	0	-0.003	0
Winter temperature	(omitted)		0.153	0.895	0.011	0.099

Level of education of the household head was positively associated with the use of agroforestry and the use of erosion control as an adaptation option. A unit increase in education results in an increase in the likelihood of using agroforestry and erosion control respectively. The age of the household head was positively associated with the use of erosion control and irrigation and a disincentive to the use of changing of time of activities, improved cook stove and migration. A unit change in the age of the household head increases the likelihood of the use of erosion control and irrigation by 0.3% and 58% respectively, while it decreases that of changing of timing of activities, use of improved cook stove and migration by 0.6%, 40.5% and 1.2% respectively. Primary occupation (farming) was negatively associated with the use of agroforestry as an adaptation option and decreases the likelihood of its use by 7.3%.

The mode of transportation to the market was positively associated with the use of agroforestry, changing of the time of operations, use of improved cook stove, migration and negatively associated with the use of erosion control. The use of motorized means of transportation results in 18.3%, 22.7%, 46% and 11.3% increases in the likelihood of the use of agroforestry, change of time of activities, migration and use of improved cook stove respectively, while it decreases that of the use of erosion control and irrigation by 22.6% and 9.7% respectively. Access to electricity encourages the use of erosion control and irrigation and was negatively associated with the use of agroforestry as an adaptation option. A unit increase in electricity access increases the likelihood of the use of erosion control and irrigation by 17% and 35.1% respectively and decreases that of agroforestry by 22.2%. Net revenue from the forest has a positive association with the use of improved cook stove (ICS) and a unit increase in revenue increases the likelihood of its use by 6.4%. While the number of years of forest use (experience) was positively associated with changing the time of operations and the use of cultural practices, but it was negatively associated with the use of ICS. A unit increase in the number of years of experience in forest resource use increases the likelihood of the use of changing of the time of operations and cultural practices by 0.6% and 0.4% respectively, while it decreases the use of ICS by 10.7%. The number of extension visits was positively associated with the changing of the time of operations, increase sing the likelihood by 2% and decreased the use of agroforestry by 2.4%. Distance to the market was positively associated with the use of improved cook stove and negatively associated with the use of irrigation. A unit increase in the distance to the market increases the likelihood of the use of ICS by 28% and decreases that of irrigation by 16.5%. Detecting climate change positively influences the changing of the time of operations and the use of agroforestry. A unit increase in the farmers' detecting climate change increases the use of agroforestry and change of time of activities by 50% and 21.2% respectively.

Average rainfall was shown to be prominent in influencing agronomic practices (agro-forestry and erosion control). Dry seasons (winter) rainfall encourages the practice of agroforestry; the establishment of nursery, planting and establishment of the trees after planting are rainfall dependent. A unit increase in dry season rainfall increases the likelihood of the practice of agroforestry by 1.2%. During the dry seasons there is usually little rain, thus having water supply at this period increases agroforestry practice. Rainfall during this period is usually not too heavy to affect planting operations, cause water logging, inhibit fruit ripening or affect harvesting process. On the other hand, winter and spring temperature are negatively associated with agroforestry; unit increase results in a corresponding 1.9% and 0.8% decreases in the likelihood of agroforestry practice respectively.

The beginning of the spring period (March and April) is too dry to plant tree crops and in most parts of Nigeria is the peak of dry season. In addition the harvesting of most fruits would have been completed before then and fruit trees have shed their leaves, waiting for the next rainy season. This result also conforms with that of cultural practices which shows that autumn (September – November) temperature favours agronomic practices in agroforestry system; planting, fertilizer application, weeding, pruning, budding and grafting. This is because of the reduced rainy season and relatively drier environment for these practices, which are done before the onset of the dry season that starts at the later part of the winter and peaks at the early part of the spring. In the case of the summer temperature and rainfall, they both negatively affect cultural practices. A unit increase in both results in a corresponding decrease in the likelihood of use of cultural practices by 0.7% and 0.3% respectively. The period is too damp for any meaningful activity in the forest / farm, it inhibits the collection of forest products and causes fruits to rot, fuelwood is damp and most people are forced indoors, especially during the peak of summer rainy season when it rains for several days non-stop. In addition a higher temperature in the damp environment encourages fruit putrefaction, pest / insect multiplication and disease outbreak, thereby reducing output. There is no doubt that spring rainfall positively influences erosion control as the later part of the spring season is usually the beginning of the rainy season which often is characterized by floods, farmers are kept busy channeling water out of their farms and clearing water ways. During the peak of the rainy season (summer) the reverse is the case as excessive rain makes it difficult for any meaningful activity. Subsequently, when the rain subsides (autumn) season major works are done by farmers and communities on gullies formed during the rainy season before the onset of dry season when the soil is too hard to work.

4.0 Discussion

The main adaptation strategies identified in this study are agroforestry, erosion control, changing date of operations, use of ICS, cultural practices, irrigation and migration. Among these, the use of different cultural practices and the practice of agroforestry appear most important among adaptation strategies of forest communities to climate change. Cultural practices are an amalgam of different agronomic practices like pruning, mulching, use of fertilizer, weeding, fallowing, building of shades and use of resistant varieties. Agroforestry is a win-win adaptation options available to the forest communities in the face climate change, especially with respect to incentives accruable via the nascent carbon market. It is also widely recognized that forests play an important role in the global carbon cycle by sequestering and storing carbon (IPCC, 2000; 2014; Karjalainen *et al.*, 1994; Stainback and Alavalapati, 2002; Nyong *et al.*, 2007). According to Verchot *et al.* (2007) agroforestry can enhance productivity, contribute to climate change mitigation and strengthen the system's ability to cope with adverse impacts of changing climate conditions. Thus, the agroforestry component of the REDD+ initiative should be fast tracked as a win-win option for carbon climate change mitigation and building of resilience among the forest poor (Minang, 2013). Agroforestry tries to find some balance in the raising of food crops and forests (Adesina *et al.*, 1999) and makes important contributions to rural livelihoods (Sunderlin *et al.,* 2005; Sivakumar *et al*. 2005). According to Verchot *et al.* (2007) agroforestry contributes to reducing farmer vulnerability to mid-season droughts and offers opportunities for improving rural livelihoods by turning unproductive land into productive land. Due to being able to tolerate inter-annual variability in rainfall, deep rooted tree-based systems have some obvious advantages for maintaining production during wetter and drier years; Charles *et al.* (2013) found that agroforestry practitioners were richer than non-practitioners with an extra US$618 income annually as economic yields from marketable tree products compensate for the loss of crop yield Integrated forest agro systems are common in southern Nigeria where shade tolerant crops such as *Dioscorea spp.* and Cocoyam are incorporated within permanent forest settings (Adesina, 1988). The adaptation options identified in this study resonate with adjusted planting dates and new varieties in Greece (Kapetanaki and Rosenzweig,1997), new hybrids and changes in sowing dates in Spain (Iglesias and Minguez, 1997), altered crop mix, crop varieties, sowing times, harvesting dates, and water saving technologies in the United States (Kaiser *et al*., 1993; Kaiser *et al*., 1993); varying planting dates, using different crop varieties, different cultural practices, soil and water conservation in sub-Saharan Africa (Hassan and Nhemachena, 2008; Wehaa *et al*., 2013). Those whose primary occupation was farming were shown to be averse to practicing agroforestry. This could be due to the technicalities involved; the subsistent nature of agriculture in rural Nigerian communities where the priority is given to arable crops for families' consumption. In addition, the practice of agroforestry requires large areas of land, contrary to the fragmented small pieces of land holdings by the farmers in most of the rural communities of Nigeria. This is also made more complex with the lease system of farming where most farmers crop on other peoples' lands and therefore are not allowed to invest in more permanent ventures.

Most of the household heads identified in this study were middle aged males with primary school education; this is in line with the findings of Chhetri (2005) that community forest income to the male headed and illiterate household in Nepal was higher than those of female headed and literate households. Mukasa *et al.* (2012) and Cassidy and Barnes (2012) also found that forest activities are dominated by males. Thus, most women benefit from forests indirectly through their husbands or male relatives (Mukasa *et al.,* 2012). In this regard there is the concern that the problem of traditional male dominance in the realm of forestry limits the degree to which forest departments around the developing world are motivated and capable of initiating and implementing gender equality agenda (Gurung and Lama, undated). Thus, there is a need to develop more appropriate options for women, like socially conditioned inequities in access, use and control of forest resources in order to reduce the gender gap in the system (Adesina *et. al.* 2000).

The negative association of summer rainfall (rainy season) to different adaptation strategies, and consequently output, was due to excessive wetness that makes it difficult for farmers to get into their farms, cause some vegetables products to rot and encourages fungus which damage crops, especially those that have fruits close to or in the ground (Sosnowski, 2013). Problems of excess rainfall also cause fruit to crack or split (Marshall *et al.,* 2002; NeSmith, 2005) and causes diseases, delays ripening, destroy or reduces flowering and reduces yields (Johnson, 2013).The positive association between age and different adaptation strategies resonates with those of Deressa *et al.* (2009) in Ethiopia and Baffoe-Asare *et al.* (2013) in Ghana. The result may also reflect that older farmers have more money over the years to implement long lasting investments in their farms, have more equity to enable them to borrow from commercial institution and also have more grown up members of their families, with older children to assist in on-farm activities. This finding also resonates with the that of Cassidy and Barnes (2012) that ages of the household head was positively correlated with social connectivity and resilience and the older the children the freer are the parents for economic activities that build resilience (Andersen and Cardona, 2013). This finding also relates to the positive relationship between household size and erosion control; because the family has more labour force for these operations. The fact that innovation take-up and social resilience are positively associated with household size has also been demonstrated in the work of Baffoe-Asare *et al.* (2013) and Cassidy and Barnes (2012).

Older farmers are more reluctant to migrate in the face of adverse climate change effects; considering their land assets and longtime investments on the farm, they are not easily able to change their activities (Hutton and Haque, 2004; McLeman and Smit, 2006; Johnson *et al.,* 2013). There is the tendency for one to remain even in the face of adversaries, due to deep social ties to relatives, friends and associates. Households in the rural areas use migration as a risk management strategy when faced with rainfall variability and food and livelihood insecurity (Warner, 2012). Migration as an adaptation strategy is not a new phenomenon; it has also been reported in the Sahel and Sudan (Afolayan and Adelekan, 1998; Hammer, 2004), Papua New Guinea (Barnet and Webber, 2010), Tanzania (Charnley, 1997) and Ethiopia (Meze-Hausken, 2000).

The number of years of experience individuals have been involved in forest activities was positively associated with the use of diverse cultural practices and also changes in their activities with emerging climate change impacts. This is in agreement with the finding of Negash (2011) in a study of farmers' preference for adaptation strategies in Ethiopia, Rana *et al.* (2012) in India and Baffoe-Asare *et al.* (2013) in Ghana. Age is adversely associated with the adoption of changing of activities as an adaption option; this was also found by Ekwe and Onunka (2006) in Nigeria and Rana *et al.* (2012) in India. These findings are not unconnected with the reluctance to innovate by the older people, due to the fear of uncertainty and the quest for food security and not 'profit' in subsistence agriculture. Age of the household head was also negatively associated with the use of ICS. El Tayeb and Mukhtar (2003) also found out that age of wives, had negative significant effect on the adoption of ICS in Sudan; possibly the long time users of open fire cooking are more reluctant to adopt ICS due to cultural beliefs and inertia associated with long time practices. For the cost implication associated with the change. Ergeneman (2003), Jagadish (2004), Rai and McDonald (2009), Holme (2010), Inayat (2011) and Mobaraka *et. al.* (2012) observe that an obvious disadvantage and barrier to adoption of improved cook stoves is that they cost money. For most low-income consumers, ICS are simply not affordable with disposable income (Rai and McDonald, 2009; Slaski and Thurber, 2009), and the economic situation of subsistence populations is such that they do not see the long-term benefits for the short-term cost of the ICS (Manuel, 2003). The amount of income from a system is usually a positive incentive to invest in strategies to protect the system from adverse climate change impact, and the forest sector is not an exception. Thus, there is the need for targeted intervention by government agencies and development practitioners to subsidize the price of ICS in order to make them more affordable, or provide credit and financing for the poor (Rai and McDonald, 2009). It was expected that the closer a person is to the market the more likely the adoption of ICS, but the reverse was the case: it could be that the markets where the ICS are procured are further from the rural areas (Appendix 1). In the same vein, mode of transportation to the market was positively related to the use of ICS, i.e. the more the time taken to go to the market the more likely the use of ICS, thus, showing that those that use motor and transport to the market, who are more probably richer are more likely to use ICS. More widely the mode of transportation was also positively related to agroforestry, changing the time of activities and migration. In all of these situations it shows that those that have access to motorized forms of mobility are more versatile and adaptive to changing environmental conditions than those that have not. In the case of agroforestry, the use of vehicles help in the evacuation of products to the market for sale, it helps to make migration easy and makes the work of the farmers easier especially when they need to reschedule operations in the farm, as it is more convenient to adjust operation times when there is a motorized form of transport than when there is none. In the case of the negative effect of mode of transportation to erosion control, it is possible that those who have motorized forms of transport are relatively more affluent and mobile, so can easily change farming sites in the event of erosion and / or can afford less erosion prone sites for their farming than others, so have no need to control erosion. Education was positively associated with the practice of agroforestry as against the traditional arable crop agriculture. Deressa *et al*. (2009), Baffoe-Asare *et al.* (2013) and Hassan and Nhemachena (2008) also found that education was positively related to the use of adaptation options in their analysis of the determents of farmers' strategies for adapting to climate change: those with better level of education have also been found to exhibit greater level of resilience against adverse climate change impact (Tesso *et al.*, 2012). Educated farmers have greater understanding of the importance of tree planting and the incorporation of trees as part of farming practices, especially appreciating the concept of carbon storage and Nitrogen fixation in the case of the use of leguminous trees.

Those that have access to electricity were shown to be more likely to invest in irrigation on the farms. This result is in agreement with that of Hassan and Nhemachena (2008) in their study of African farmers' strategy for adapting to climate change. This is because electricity is very essential in the powering of most on-farm irrigation facilities. It could also be probably true that those with access to electricity are more well-off and could therefore afford to use electricity and as well irrigation. As in Ethiopia (Deressa, *et al.*, 2008), age of the household head also has a positive association with irrigation; due to the long period of involvement in agro-forestry activities by the older farmers which has predisposed them to invest in irrigation infrastructure with their accumulated capital and experience compared to the young entrants. Thus, it is most likely that the positive association between education and erosion control is linked to the need to protect irrigation facilities, crops, farm assets and other investments in the farm.

Awareness of climate change was reflected in the findings on the number of extension visits and notice of climate change which were positively related to changing the time of activities. Rana *et al.* (2012) and Fatuase and Ajibefun (2013) also found that the more the farmers have access to extension services, the more the chances of adopting different adaptation measures, including changing the dates of farm activities in India and parts of South Western, Nigeria respectively. Nhemachena and Hassan (2007) and Deressa *et al*. (2011) found access to extension agent to influence the adoption of different agronomic practices in Southern Africa and Ethiopia respectively. Detection of climate change (change in rainfall) was also reported by Debalke (2011) as a major determinant of farmers' change of their time of operations in Ethiopia. Farmers' detection of climate change was also positively related to the practice of agroforestry; resonating with the findings of Advancing Capacity to Support Climate Change Adaptation (2010) in Ethiopia. The higher the level of awareness of climate change, either via the extension officers or by individuals' personal experiences, the more likelihood that they will adjust their operations in the face of climate change due to superior information. Thus, the need to increase public awareness and personal contact with the extension officers to update farmers with the latest issues in climate change adaption cannot be over emphasised, not only in Nigeria, but across Africa.

5.0 Conclusion

The impact of climate change is one of the serious threats facing rural forest and farm communities, not only in Nigeria but across the developing world. Many forest communities in Nigeria are implementing coping strategies that include, agroforestry, erosion control, changing dates of operations, use of ICS, cultural practices, irrigation/drainage/use of wetland and migration. Agroforestry stands out as the prominent strategy for its obvious win-win benefits; it has a particular role to play in mitigation of atmospheric accumulation of GHGs, increase in the amount of organic matter in the soil which help to improving agricultural productivity. There are many adaptation options, which, if adequately designed and applied in response to specific local contexts and realities, can limit the negative effects of climate change and land degradation not only in Nigeria but across West Africa. Many of these options combine land conservation and productivity enhancement practices to build resilience among rural forest communities and are already familiar to most of the local communities, but their effectiveness now depends on careful incubation, selection and application, so that they are implemented in the right place and at the right time, combined with an enabling policy environment for the adaptation options to be practiced in a sustainable manner (UNDP, 2009). Communities already have a long record of successful adaptation to climate variability, however, if we are to meet the goal of agricultural transformation we must help poor rural people cope with climate change.

Appendices

Appendix 1. Household heads' attributes

Age of household head	
Variable	**Percent**
20 and below	3
21 – 30	5
31 – 40	20
41 – 50	35
51 – 60	24
61 – 70	10
71 – 80	4
81 and above	1
Total	100
Gender of household head	
Variable	**Percent**
Female	27
Male	73
Total	100
Household size	
Variable	**Percent**
1	201
2	10
3	9
4	25
5	8
6	6
7	4
8	13
9	6
Total	100
Level of education of household head	
Variable	**Percent**
0 – 6	46
7 – 12	24
13 – 16	26
17 and above	5
	100
Primary occupation of household head	
Variable	**Percent**
Farmer	64
Others	36

Appendix 2. Households' forest resource use attributes

Access to electricity

Variable	Percent
No access	41
Access	59
Total	100

Number of years of forest use

Variable	Percent
1 – 10	21
11 – 20	53
21 – 30	15
31 – 40	7
41 – 50	3
51 – 60	1
Total	100

Distance to the market (Minutes)

Variable	Percent
1- 30	40
31 – 60	51
61 – 90	9
Total	100

Mode of transportation to the market

Variable	Percent
Trekking	34
Motor	66
Total	100

Number of Extension visit per year

Variable	Percent
0	94.5
1 – 4	3
5 – 10	.2
11 – 15	2
16 – 20	1
21 and above	.3
Total	100

Notice of climate change

Variable	Percent
No notice of climate change	12
Notice climate change	88
Total	100

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5.4 Cost benefit analysis and barriers to climate change adaptation

Adaptation to climate change is seen as an investment. Assuming limited resources, decision makers are constantly faced with an optimization problem in resource allocation so as to get the highest net benefit, welfare, income at the lowest possible cost (Noleppa, 2013). Thus, how much should be invested in which adaptation option(s) and at what time in order to create the highest benefit at reasonable costs and within the available budget? (Noleppa, 2013). It is based on this notion that IPCC recommend that effective adaptation process should identify options for adapting to climate change and evaluate them in terms of criteria such as availability, benefits and costs, effectiveness and efficiency (McCarthy *et al.,* 2001).

Having therefore looked at all other areas of climate change perceptions, impact and adaptation options and determinants, this work would be incomplete without looking at the issue of cost and benefit (economic assessment) of alternative adaption options, which is what is achieved in this section.

In economic assessment of adaptation, the benefits and costs are usually measured in monetary terms, and with efficiency and effectiveness serving as a sort of a quotient or ratio of both cost and benefits (Noleppa, 2013). Along this line three distinct methods are suggested

- ✓ Cost-benefit analysis (CBA);
- ✓ Cost-effectiveness analysis (CEA); and
- ✓ Multi-criteria analysis (MCA) (UNFCCC, 2002; Niang-Diop and Bosch, 2011)

All three approaches are able to (1) analyze and (2) prioritize adaptation options. According to Noleppa (2013), CBA has the added advantage of measuring costs and benefits of alternative adaptation options and translating them into monetary terms. But if benefits of adaptation options can be quantified, but not expressed in monetary terms (e.g. human lives), whilst costs can be quantified in monetary terms, a CEA would be preferred. If both costs and benefits cannot be expressed in monetary terms, an MCA is recommended. Else an economic approach is very difficult to be applied and other approaches have to be taken into consideration (Noleppa, 2013).

Estimates on adaptation benefits are mainly reported in terms of increases in yield or welfare, or decreases in the number of people at risk and adaptation costs are usually expressed in monetary terms, while benefits are typically quantified in terms of avoided climate impacts, and expressed in monetary as well as nonmonetary terms (e.g., changes in yield, welfare, population exposed to risk), hunger (Adger *et al.*, 2007). In this study the CBA method was used to estimate the benefits of adaptation options.

5.4.1 Theoretical framework

Climate change is an exogenous shock to the economy and adaptation is a response to that shock (Wheeler and Tiffin, 2009). Although Callaway (2004) argues that this adaptation to climate change is essentially private since the consequences of the adaptation action can be excluded and therefore accrue primarily to their instigator, one reason for evaluating the costs of adaptation is to determine the optimal combination and level of adaptation and mitigation. In this context it is important to recognize that what we seek is a measure of the opportunity cost that is forgone as a result of us needing to adapt to climate change; in the absence of climate change individuals might have equally spent their money on other fruitful ventures that yield benefit (Wheeler and Tiffin, 2009). What therefore matters is the additional expenditure that is necessary to adapt. Once we have measured a cost of this sort it is important to recognize its significance. CBA is all about measuring the distinction between static and dynamic costs. In a static approach the cost that is measured is one that compares two discrete situations, one with climate change and one without. So if we are able to financially abstract that benefit accruing due to the implementation of an adaption strategy then we can use CBA approach to economic valuation**.**

In cases where no market valuations are available for the outcomes then evaluation using the willingness-to-pay principle is done – i.e. the benefits are set equal to the value of the resources expended for the project (Willenbockel, 2011). The fundamental principle in economic valuation is to make a positive contribution to economic welfare, so it is expected that the accruing economic benefits attributable to the project must exceed the total economic costs of the resources used in the course of the project, as well as the opportunity costs of the human and material resources contributed by local households and other stakeholders (Willenbockel, 2011). The concept of this principle is summed up in the position of Chambwera and Stage (2010) that:

> *"Even if there are no government adaptation measures, many firms and households will change their behaviour as a result of climate change, and as a result of this autonomous adaptation they will be better off than if they had ignored climate change in their decision-making. In many countries, however, the net effect of climate change will nonetheless be that aggregate social welfare is lower than it would have been without climate change. ….these adaptations reduce costs (reduced cost), but not completely, such that there will always be residual damage costs. The difference between the cost of climate change without adaptation and the residual cost of climate*

change after adaptation is the gross benefit of adaptation (added return), including the cost of adaptation (added cost) reduces the benefit to the net benefit of adaptation (reduced benefit)" (Chambwera and Stage, 2010). (Parenthesis mine)

Bearing this in mind therefore, efforts were made in this study to pick every bit of cost and benefit feasible and translate them into monetary terms with the help of the interviewees themselves, local leaders and expert advice from scholars based on economic theory and other similar works.

Previous approaches (e. g. McCarl, 2007), have been criticized for just taking the current state and add a more or less arbitrary amount to represent the additional costs of adaptation, thereby making it very hard to judge whether the magnitude of the figure is reasonable without trying to take a bottom-up approach to costing (Wheeler and Tiffin, 2009). It is this 'bottom-up approach' gap that this work fills by directly measuring adaptation cost and benefit with data from the rural forest communities who do the adaptation, make the expenses and receive the benefits thereof, thus, they can tell the story better.

5.4.2 Cost Benefit Analysis

Cost Benefit Analysis basically compares costs and benefits of an intervention over time (GSF, 2011), so long as all the costs and benefits are quantifiable in monetary terms. In the analysis damages that can be avoided through the adaptation option in question count as benefits and If not all of the benefits and costs are accountable in monetary terms per se, a CBA is still possible if achievements towards an objective can indirectly be translated into monetary units (Chambwera and Stage, 2010). Thus, fulfilling the conditions for CBA are: that all the costs and benefits are quantifiable in monetary terms (added return / cost) and that damages avoided or incurred through adaptation are quantifiable (reduced cost / benefit) (Chambwera and Stage, 2010) The outcome of a CBA are Net profit, benefit cost ratio, Net present value and internal rate of return.

5.4.3 Net profit

Net profit is given as total revenue (added Benefit + reduced cost) – total cost (added cost + reduced benefit) (fixed and variable cost). Added benefit or cost is the gain or cost incurred in as a result of taking up a particular adaptation, while reduced cost or benefit is the reduction in the cost of activities as a result of improved method of production (say technology) or reduction in benefit as a result of the introduction of a new method in the production process, respectively.

5.4.4 Net present value (NPV)

Net present value is a first main output of any CBA. The NPV is simply benefits minus costs calculated at their present value, i.e. using a discount rate for future benefits and costs (UNFCC, 2011; Noleppa, 2013). If the calculation leads to a positive NPV, then an adaptation measure makes sense from an economic point of view; that is, NPV should be greater than zero for an option to be acceptable (UNFCC, 2011). The better the economic value of an adaptation measure is the larger the NPV becomes. In the NPV, a target rate of return is set which is used to discount the net cash inflows from an adaptation. Net cash inflow equals total cash inflow during a period less the expenses directly incurred on generating the cash inflow. Standard economic theory tells us that the NPV results are the main summary of how worthwhile an action such as adaptation is (Hope, 2009)

Net Present Value is therefore given as:

$$NPV = \sum_{n=0}^{N} \frac{(b_n - c_n)}{(1+r)^n}$$

Where

NPV is the net present value;

b_n is the benefit in year n;

c_n is the cost in year n; and

r is the discount rate (Hunt and Taylor 2008)

n are the number of periods during which the project is expected to operate and generate cash inflows (Hunt and Taylor 2008)

However, a larger NPV does not necessarily indicate higher efficiency. If the objective is efficiency, i.e. the highest benefit per unit spent, another output indicator needs to be calculated, namely the ratio of benefits and costs. The larger the benefit cost ratio (BCR) becomes, the better the adaptation option is judged to be.

5.4.5 Benefit cost ratio

The benefit-cost ratio (BCR) is the ratio of the present value of the benefits to the present value of the costs. It estimates the level of efficiency of the adaptation process (UNFCC, 2011; Noleppa, 2013). In other words, what is the return per unit dollar investment in the particular adaptation option; if high positive), usually greater than 1, it is efficient, otherwise it is inefficient. Benefits and costs are each discounted at a chosen discount rate. The benefit-cost ratio indicates the overall value for money of a project and can therefore be used to priorities the allocation of finite adaptation funding (UNFCC, 2011)

5.4.6 Internal rate of return

The internal rate of return – that is the discount rate at which the total cost would just be equal to total benefits in present value terms, i.e. the discount rate that makes the NPV equal to zero

(UNFCC, 2011). For any discount rate below this level, the net welfare gain attributable to the project initiatives is positive (Willenbockel, 2011). The higher an option's IRR, the more desirable it is.

5.4.7 Estimation procedure

Aware of the shortcoming of CBA approach to estimating cost of adaptation which is that all cost and benefit must be measured in monetary terms, efforts were made to capture the different costs and benefits (or opportunity costs) due to each adaption options from the respondents themselves and comparing them with economic theory and expert advice from knowledgeable members of the communities where the research was undertaken.

Chambwera and Stage (2010) are of the opinion that there is no universal discount rate, and assumptions about discount rates differ from country to country, with the time period involved and whether a study is local, national or global, thus most analyses that employ discounting choose a discount rate through a combination of theoretical objectivity and ethical discretion. In fact most benefit/cost analyses are criticized for the discount factor used including the well celebrated Stern Review having the highest criticism, centered on the choice of the discount factor. This therefore suggests that there will not be one correct answer, implying that some kind of sensitivity analysis, using a range of different discount rates, will likely need to be applied in most studies (Chambwera and Stage, 2010), hence the key issue for any economic analysis is to use a discount rate that makes reasonable assumptions and that give plausible results. Therefore looking at the cost of capital in Nigeria and the rate used by other studies, including the recommendation of the Asian Development Bank (Chambwera and Stage, 2010; UNFCC, 2011; Willenbockel, 2011; Noleppa, 2013), a discount rate of 15% was used in this analysis, while using 10% and 20% for sensitivity analysis. Since most of the adaptation options were only last for a short term of one to five years a time frame of 3 years was used for the analysis, assuming equal amount of benefit for each of the years.

5.4.8 Results

The adaptation option with the highest CBA in all the cases was the use of improved cook stove (ICS), others were bush fallowing and irrigation (Table 1 and fig. 1 – 4). On the other hand, the use of fertilizers and agrochemical had the lowest benefit in all cases and was in the negative, followed by investment in erosion control.

Table 1: Cost – Benefit analysis of climate change adaptation options among forest communities in Nigeria

	Net Mean Benefit		Benefit Cost Ratio	NPV					
				0.1		0.15		0.2	
	USD	₦		USD	₦	USD		USD	₦
Building shade	45.00	7200	1.2	3.41	545.45	1.63	20.00	0.00	0
Changing time of operation	119.46	19112.9	3.35	72.94	11670.53	68.22		63.89	10222.58
Erosion control	48.46	7753.48	0.4	-116.96	-18714.28		235.03	0.00	
Increase use of fertilizers and chemicals	-10.76	-1721.74	-0.18	-77.32	-12370.52			0.00	
Increased weeding	69.33	11092.13	1.46	15.62	2498.65	12.9	-60.07	10.36	1658.33
Increase in fallow period	179.90	28783.33	27.41	156.98	25116.67	149.9		143.35	22936.11
Migration	101.28	16205.56	1.02	-7.51	-1201.01		#NUM!	0.00	
Mulching	39.55	6327.83	1.05	-1.57	-251.59			0.00	
Agroforestry	65.64	10502.6	0.44	252.71	40433.91	178.9	46.24	124.57	19931.85
Use of resistant varieties	142.61	22818.3	2.79	78.46	12553.43	72.9		67.65	10824.77
Irrigation	116.40	18623.2	2.87	400.64	64102.15	349.6	2641.27	307.50	49200.33
Use of improved cook stove	453.48	72556	4.65	1621.53	259444.3	1422.62		1258.67	201386.85

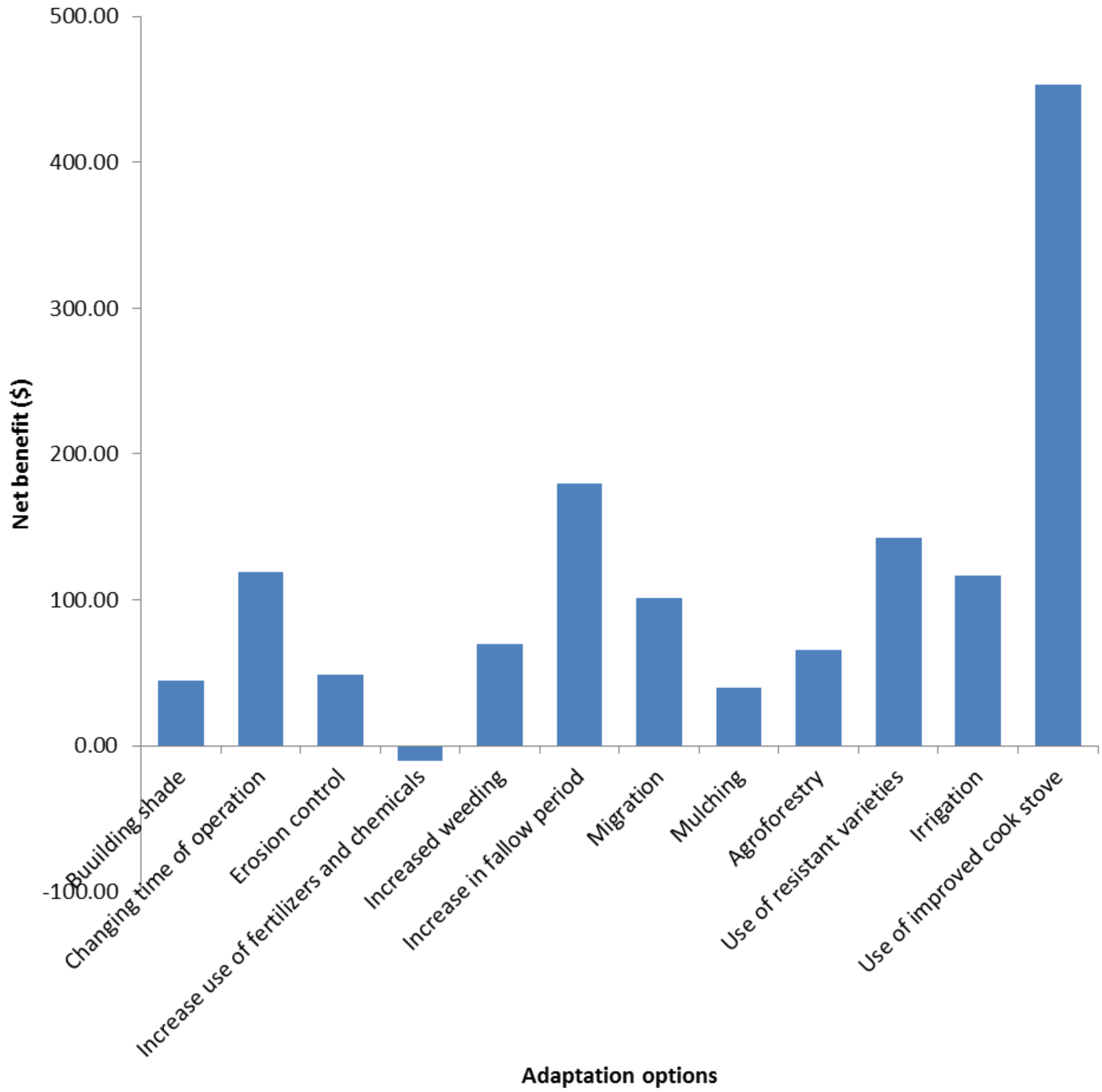

Figure 1. Net profit from adaptation options

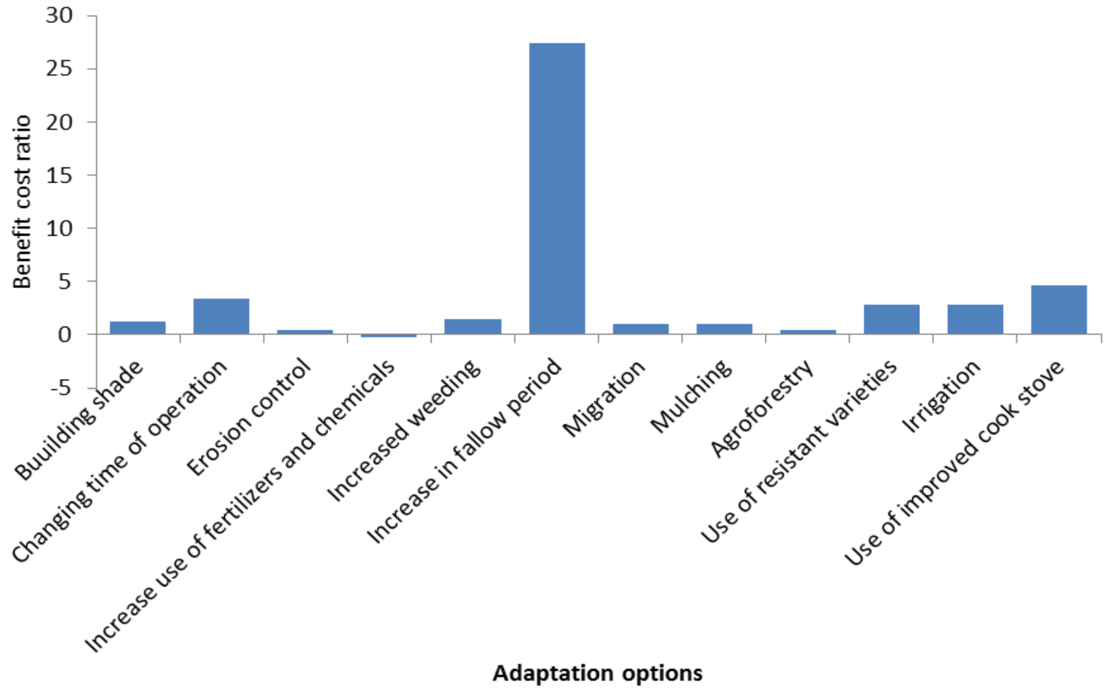

Figure 2. Benefit cost ratio of adaptation options

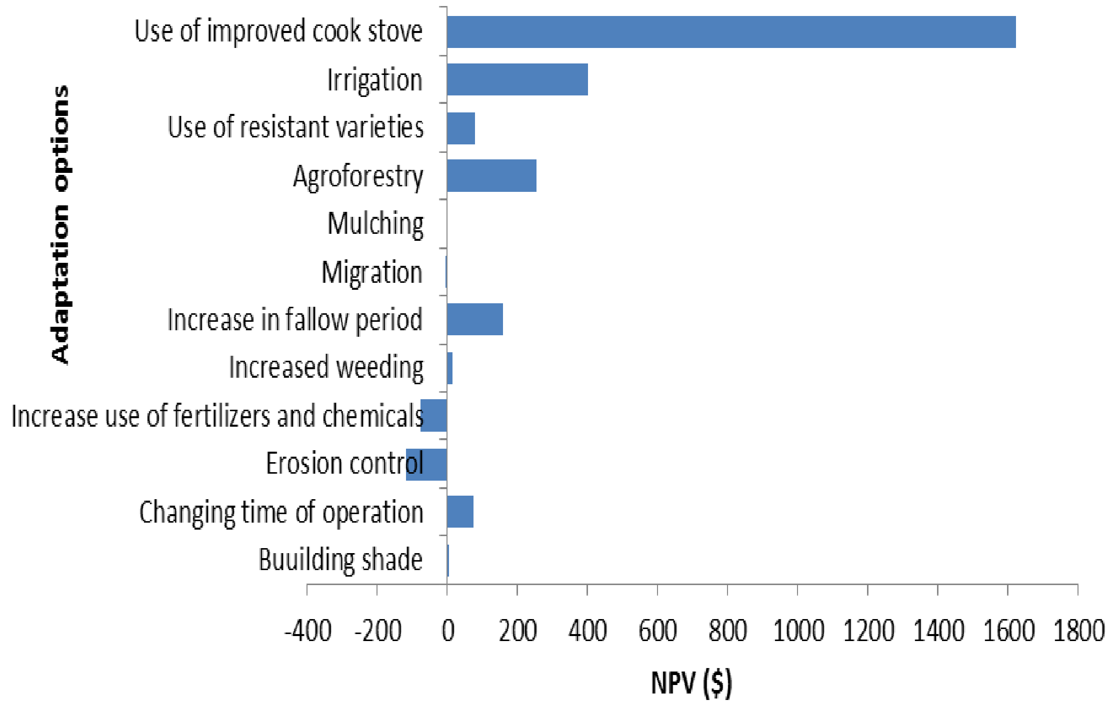

Figure 3. NPV of adaptation options at 10% cost of capital

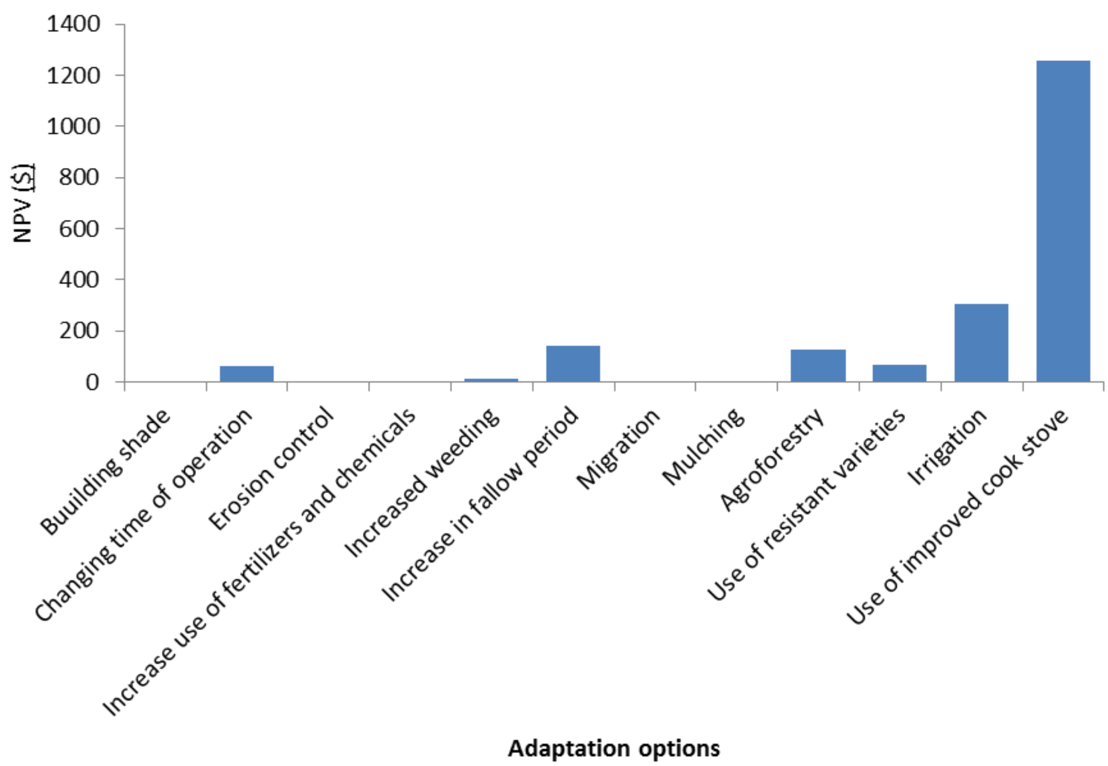

Figure 4. NPV of adaptation options at 20% cost of capital

Constraints to adaptation options

With respect to barriers to adaptation, results show that the more observed obstacles are poor infrastructure, poor access to credit facilities, finance and high cost of fertilizer and chemicals (Table 2). On the other hand communal land ownership, access to irrigation facilities, access to land and other inputs rank low among the barriers.

Table 2. Barriers to climate change adaptation among forest communities in Nigeria

Constraints	N	Min	Max	Mean	S. D.
Communal land ownership	284	1	5	2.5	1.51
High cost of irrigation facilities	209	1	5	3.01	1.67
limited land	305	1	5	3.11	1.29
High cost of farm inputs	311	1	5	3.14	1.41
Traditional belief system	317	1	5	3.25	1.77
Poor weather forecast	293	1	5	3.26	1.60
Inadequate knowledge on how to cope	278	1	5	3.43	1.35
Inheritance land ownership	295	1	5	3.46	1.42
High cost of labour	310	1	5	3.49	1.27
Non availability of storage and processing facilities	302	1	5	3.62	1.39
Non availability of improved varieties	289	1	5	3.69	1.19
Poor access to information / extension services	309	1	5	3.98	1.24
High cost of fertilizer and chemicals	313	1	5	4.14	1.15
Limited income	335	1	5	4.20	0.99
Non availability of credit facilities	325	1	5	4.20	1.14
Poor infrastructure	324	1	5	4.33	0.94
Other constraints	16	1	5	4.44	1.37

5.4.9 Discussion

It is not surprising that the use of ICS had the highest return on investment among all adaptation options; this is because of the massive saving in the quantity of firewood used in cooking among those that have adopted the innovation. In some cases up to three quarter of fuelwood is saved compared to what is the case in open fire stove. This has resulted in huge savings in monetary terms for those households that buy their fuelwood and saving of time, energy and risk associated with fetching firewood among those that go to the forests to collect them. Thus ICS has been referred to as a trailblazer and a win-win option in the quest to climate change mitigation among the rural forest communities in Nigeria. The case of bush fallowing, is obvious as there is usually no or low investment in bush fallowing as the lands are just left fallow to regenerate over a few years before they are put into cultivation again. In this case the lands are regenerated under natural conditions with minimum interventions and the soil is fertile once again for cropping compared to lands that are continuously cropped. For those that use irrigation, especially during the dry season, it was shown that their margins are far higher than those that don't due to their ability to put their products to the market during seasons when they are not available in the markets, thus attracting higher premium for the products.

On the other hand the use of fertilizer and agrochemicals as climate change adaptation options are shown not to be cost effective due to the high cost of such inputs in the country. In most cases the farmers are ripped off by middle men who sell them at very high costs. Those that get them from government agencies also have the problem of not getting the inputs as at when due, such that they arrive at odd times when their crops have passed the optimum stages for application and they are useless to the crops or are even inhibitory to crop yield. Thus, such investments become useless; a frustrating situation in Nigeria that has led to the direct government interventions since 2012, by creating the input wallet system, in which case fertilizers are sold directly to the farmers at subsidized rates without the use of the middle men. This result is also in agreement with those of the barriers to adaption which show that poor access to fertilizers and other agrochemicals is an obstacle to effective adaptation to climate change. Erosion control has also been shown not to be cost effective as an adaptation option as the investment in erosion control is usually high and does not translate to increased output; rather eroded lands are very poor in crop yield. These results are in resonance to the work of Njie *et al*. (2006) who investigated climate change impacts and adaptation costs and benefits for cereal production in the Gambia and found out that net benefits were not necessarily positive for all adaptation strategies.

Barriers to climate change adaptation such as poor infrastructure is an endemic problem in Nigeria; with poor electricity, water supply, rural roads, health facilities, all militating against the ability of the rural dwellers to effectively take up various innovations, especially those that are directly linked to the use of those facilities. Such adaptation options like irrigation and agroforestry need all or some of water, electricity and good roads to be effectively adopted, and where such facilities are lacking it becomes impossible to adopt them. Associated with these barriers is the poor access to credit facilities and income to finance their adaptation process. These and other barriers are therefore part of a plethora of constraints faced by the rural forest communities in terms of climate change adaptation in the country.

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CHAPTER SIX

Summary, Conclusion and Recommendations

6.1 Summary

Climate change has been shown to have adverse impacts on the global economy. Alhough the levels of vulnerability differ from place to place and sector to sector, developing economies are projected to be most vulnerable due primarily to their dependence on climate sensitive natural resource base like agriculture and forestry and the prevalence of poverty, low infrastructure and low capacity to adapt. Ironically, Nigeria is classified as one of the countries in this group (NEST, 2004; IPCC, 2007; Apata *et. al.,* 2009), despite its vast wealth and economic potentials made possible by oil revenue; this is because of the inability of successive governments to translate this oil wealth to impact on the welfare of its citizenry.

Prior to the 1960s, agriculture was the mainstay of the Nigerian economy, providing economic prosperity to the nation and its citizens who were actively involved in agricultural productions and were reaping the benefit thereof. The discovery of oil in the late i960s and the dramatic rise in world oil prices in 1974 caused a sudden flood of wealth to Nigeria. Much of the revenue was intended for investment to diversify the economy, but the scramble for the oil money at the centre spurred indolence and underscored inequities in distribution and pushed agriculture, the traditional mainstay of the economy, from the early fifties and sixties, to the back. It therefore means that there lies in the country a latent potential to make agriculture and forestry prosper once more as a key contributor to national income and economic revival of the citizenry, as has been the focus of the present government lately in the Agricultural Transformation Agenda. This transition cannot be made without due consideration to the vulnerability of the sectors to climate change and possible adaptation mechanisms in that respect.

This study was therefore borne out of the need to bridge this gap and provide evidence for policy. The study was set out to investigate the social perspective and economic impacts of climate change on forest resource use and indigenous and cost effective adaptation options used by forest communities in Nigeria.

It is shown that the problem with Nigeria with respect to climate change adaptation and mitigation is not necessarily that of lack of policies, institutions and regulations, but the lack of government initiative for policy implementation, lack of sufficient empirical evidence regarding Nigeria's vulnerability to climate change and the lack of appropriate mechanisms to assess the impact of existing policies. Thus, there is an urgent need for Nigerian government to develop a climate change tracking system, develop and faithfully implement policies and regulations towards climate change mitigation and adaptation in order to build the resilience of agrarian forest communities to climate change and avoid a catastrophic feedback on the oil cantered, but agricultural dependent economy. This dependency on the forest system has been shown to be high in Nigeria; the level of livelihoods derive from the different ecological regions of Nigeria is highest in the mangrove ecological region (47%) and declines towards Sudan savanna (14%), while the predicted average value of annual household income from the forest was estimated to be $3380. Majority of the households surveyed (75%) have experienced impacts of climate change on forest resources, except in the montane forest zone, thereby suggesting the resilience of the montanes ecosystem to the impacts of climate change. This notion has also been corroborated by several other studies in different places (Nadkarni and Solano, 2002; Ching *et al.,* 2011).

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Due to this high level of dependence on forest resources, excessive anthropogenic disturbances on the forest, exacerbated by the current climate change impacts which interact to limit the quantity and quality of the resource base, there is constant clashes between various stakeholders and interest groups in their struggle for the available ones. It emphasizes that resource scarcity interacting with economic pressure and political instability, have resulted in the rapid loss of arable lands in the Sahelian region of Nigeria and West Africa, leading to social crisis across the region. Furthermore a resource use, climate change conflict model was used to show that with good adaptive capacity individuals are better able to cope with climate change and are resilient. Alternatively, if individuals are not able to adapt, they then struggle with others in the same environment for whatever source of livelihood that is available, regardless of the property right status, which potentially lead to violent conflicts. This framework is also useful in designing more sustained solutions to the socio-economic and resource crisis in West Africa and across the developing economies.

The economic impact analysis of climate change on forest resource use shows that the age of the household head and level of education significantly and positively affected net revenue from the forest, which suggests that the older the household head the more likely his social and economic asset to assess forest resources like the number of family members involved in forest resource collection, also the higher the level of education the better their knowledge and skills in forest resource management. Winter and spring precipitation had positive impacts on net revenue; $1.5 and $0.28 respectively, while summer and autumn precipitation had negative impacts; -$0.073 and -

$0.05 respectively. Marginal impact analysis shows that increasing rainfall during winter and spring seasons significantly increases the net revenue per household by $62 and $75 respectively, while increasing precipitation marginally during the summer and autumn seasons reduce the net revenue per household by $42 and $18 respectively. Annual marginal increase in rainfall increases net revenue per household by $77. These results highlights the place of rainfall as a key limiting factor in tropical ecosystems; thus the provision of water during the late dry season (winter) and early rainy season (spring) for the agroforestry systems in Nigeria will be of greatly beneficial.

Despite the different results from the social perspectives indicating different kinds of climate change impacts as is shown in the perception analysis, the empirical estimation of economic impact shows insignificant impact of climate change on forest resource use, at least in the short term. This result is also emphasised by several other biophysical assays by different other scholars in other locations. This seeming discrepancy is due to the fact that the individuals' perceptions of climate change gives a picture of overall impact of climate change as perceived by the individuals, like flooding, excessive rain, delay in unset of rainfall, excessive dryness, high temperature, heat wave, river dryness among others, which are daily occurrences in Nigeria. This is corroborated by the finding which shows that over 88% of the respondents have perceived climate change in one form or the other in all the ecological regions. On the other hand the empirical estimation examined only the economic impact on forest resources use. This finding could be an indication of the resilience of the forest system to the negative impacts of climate change through carbon fertilization, specie migration and inherent plant adaptive capacity against adverse climatic conditions, as has been reported by other scholars. Furthermore, anthropogenic disturbances on the forest systems exacerbate climate change impact and make complex the abstraction and attribution of impacts by the respondents, so they dump all the impacts at the door of climate change.

The analysis of the factors affecting the individuals' ability to notice climate change shows that noticing climate change was positively associated with spring rainfall, but negatively associated with education, net income, summer and autumn precipitation. Decision to take up innovation was positively associated with access to electricity, number of years of forest use, winter rainfall and temperature, and negatively associated with summer rainfall. This is because spring rainfall has been very erratic in recent year in Nigeria; in most cases comes as usual with a long spell of dry weeks that makes it impossible for crops planted with the early rain to survive. So farmers have learnt to plant late when the rain is well established. This has made it possible for the respondents to associate it with climate change. On the other hand summer and autumn rainfall have always been normal. Also education and higher income are negatively associated with noticing climate change as most of those involved in forest resource collection are the less educated and those with lower income status in the society.

In the case of the determinants of adaptation strategies it was found that the major adaptation strategies identified were agroforestry, erosion control, changed timing of operations, use of improved cook stoves, changed cultural practices, irrigation and migration. The determinants of adaptation strategies were level of education, mode of transportation (use of motorized vehicle) to access markets, detecting of climate change, household size, access to electricity, number of years of forest use, number of extension visits and net revenue made from the forest. Primary occupation (farming) and age of the household head were shown to be negatively associated with the adoption of different adaptation options. Seasonal rainfall and temperature were also shown to be associated with the use of different adaptation options. It was also found out that the use of improved cook stove gives the highest net benefit among all adaptation options, followed by bush fallowing and irrigation, while fertilizer use had a negative return on investment, followed by investment in erosion control. Also among the barriers to adaptation infrastructure, poor access to credit facilities, finance and high cost of fertilizer and chemicals topped the list in descending order.

6.2 Conclusion and policy suggestions

Indeed, there is a general consensus among scholars from various disciplines that climate change is having and is projected to have adverse effects on the national developments of different nations, in different sectors and peoples' livelihood at different scales, nature and time depending on their levels of vulnerability / resilience. Although some sectors are shown to be more resilient than others, like the forest sector as is shown in this research. Most importantly developing nations like Nigeria are projected to bear the major brunt of climate change impact due to their level of poverty, low infrastructure, low capacity, lack of resources to adapt and high dependence on climate sensitive natural resources; agriculture and forestry. Ironically, despite the high level of awareness about the projected impacts of climate change and their consequences, most developing countries like Nigeria are ill prepared to cope with climate change impacts. Particularly Nigeria's national capability for assessing, forecasting and planning for climate change mitigation and adaptation remains inadequate and efforts in this regard are still rudimentary and fall short of expectation. So far no much research in this area has been done with respect to Nigeria, thus justifying the need for this research to provide empirical evidence for stakeholders across sectors for climate change policy, planning, advocacy and adaptive action.

This study was aimed at assessing the economic impacts of climate change, climate change perception and adaptation, cost effective adaptation options and barrier to adaptation among forest communities in Nigeria. The study relied on primary data collected from 400 rural households across different forest community in five ecological regions of Nigeria and data were analysed using different descriptive statistics, the Ricardian model, logit model and cost benefit analysis. The study showed a high level of dependency on forest resource use across the country, such that households rely on forest products for different kinds of food, employment, income, raw materials, ecosystem services, for sociocultural activities and for leisure. These products and services are continually being impacted by both human action and climate change. It shows that both age of the household head and level of education significantly and positively affected net revenue from the forest which is an indication of economic and social resilience among the households which are built on both financial and social capital over the year. That increase in dry season (winter and spring) rainfall increases household net revenue and that determinants of climate change perception, decision to adapt and adaption strategies all showed that dry season rainfall has a positive association or effect on adaption are very positive indications of a great opportunity for irrigation agriculture in Nigeria since water is the major limiting factor in agriculture and forestry in the country.

Despite the perceived indicators and individual household's account of their perception of climate change in different forms and magnitude as shown in the social perspectives of this study, the empirical estimations showed no significant impact on forest resources now and in the near future using the Ricardian model. The result provides a window of further integrated research harmonizing the social perspectives as is presented in this research and biophysical element of forest ecology and climate change. This also applies to the reduced impact of climate change on the montane ecosystem in Nigeria compared to other zones as perceived by the respondents and results from empirical estimations. The high level of climate change perception, awareness and the implementation of various forms of indigenous adaption options across all the regions is a very positive indication of the preparedness of the rural dwellers to invest in adaption, since in most cases some of those adaptation decisions are made autonomous of outside intervention. This is obvious in the results which showed that over 95% of respondents have never had any contact with extension officer, neither do they have access to credit facilities, infrastructure or farm inputs, thus, the need for the government, NGOs, advocacy organizations, international organizations and development partners to take advantage of this window of opportunity to build climate change resilience across sectors.

It is also interesting that the analysis of the determinant of adaptation, perception and adoption decision showed that attributes such as level of education, mode of transportation (use of motorized vehicle) to access markets, detecting of climate change, household size, access to electricity, number of years of forest use, number of extension visits and net revenue all had positive association or effects on adaptation. It shows that any investment in these critical economic and social security aspects of the citizenry will be a great boon on the ability of the people to adapt to climate change. This is even more reinforced by the findings on the barriers to adaptation which showed that lack of access to finance, inputs and required infrastructure; roads, water, electricity are the major constraints to adaptation. It is so because all these amenities are very essential in the process of adaptation at different degrees depending on the type of adaptation; for example finance, water and electricity are critical in the adoption of irrigation, investment in cold storage and good access road is very important in input output delivery, while water and electricity are indispensable to processing. It is therefore an urgent call to all stakeholders, especially the politicians, policy makers and international organization to refocus their investment from white elephant projects to these targeted sectors, especially in the rural areas, if they are sincere with the quest for climate change mitigation and adaptation.

Finally, despite the perceived and felt impacts of climate change the results show that anthropogenic disturbances appear to be of more importance at least in the short run, in the factors affecting land use change and forest resource use and availability in Nigeria. This has reduced the level of precision in abstracting the actual economic impact due to other factors such as climate change; which had an insignificant impact on forest resource use. Though this could be due to the characteristic resilience of the forest ecology as has been shown by other findings (Adams *et al.*, 1998; White *et al.*, 1999; Steffen and Canadell., 2005; Ravindranath *et al*., 2006; Gumpenberger *et al.*, 2010; Zelazowski *et al.*, 2011; Huntington, 2013), there is still the need for further assay in this regard, using and integrated research that combines the social, economic and biological aspects of climate change impacts assessment in a single study, this will make clearer the abstraction of impacts due to climate change.

The problem of anthropogenic disturbances arises due to the unsustainable nature of forest destruction by the citizenry, multinational and the government, without regard to environmental ethics. There is no doubt the fact that human needs in a very populous country like Nigeria is the major driver of this change, but these needs have to be met within a framework of sustainability and most importantly considering the future of our forests. This therefore calls for a strict policy framework on forest use or the implementation of already existing regulations in this regard, like the National Forest Policy (Federal Republic of Nigeria, 2006).

In this study Onyekuru and Marchant (2011) posits that the question of who will pay is at the centre of climate change economics, which guides to a great extend the decisions of our politicians whether to act or not. Ethically, developing countries believe it is not their responsibility to act as they did not cause the mess. Thus they believe that, considerations of fairness, equity and justice must inform any successful implementation of any abatement strategy. Economists and man generally is a rational animal, putting profit maximization in the fore of any investment analysis – if not how do we explain the reluctance of the U S and Russia to sign up to the Kyoto agreement. The issue is that every nation wants to act in its own interest, but that may not be the same as the global interest, this is at the centre of ethical consideration in our quest to save the earth. There is therefore the need to put aside selfish sentiments for the collective interest of combating climate change. In as much as the industrial nations are responsible for the vast majority of global pollution and therefore have the moral responsibility of funding global remediation expenses, the developing nations should start in time to cut their emission by investing in energy efficient and renewable energy potentials in their quest for development, so that they will not be subjected to emission reduction in the future. This surely will not come easy, thus there is the need for industrially advanced nations to assist developing countries with funding in this regard and provide them with technical assistance to conduct environmental and economic impact analyses and establish sound environmental practices to protect the health of their citizens (Onyekuru and Marchant, 2011).

Secondly, the economics of climate change is full of risks and uncertainties and most politicians are not ready to invest into an uninsured risk. And since investment in climate change adaptation and mitigation is an intergenerational asset, the underlying rational economic structure focuses on maximizing present day utility before thinking of bequeathing to the unborn. Contemporary politicians and political structures dare to invest in intangible assets that are not readily visible and do not benefit their constituencies directly. It is therefore an ethical responsibility on the part of the current political class to invest in climate change abatement and prioritize it in their national policy frameworks and political process as is done with other economic and capital investments regardless of its intangibility, in order to build the resilience of their citizens and economies to the predicted negative impacts of climate change. Thus, it is suggested that science, politics and ethics have to form a policy synergy for us to address climate change and do what is right, regardless of the economics and the question of who was wrong or who is to gain (Onyekuru and Marchant, 2011).

Policy implications

The forgoing analysis suggests that in order to build the resilience of the agroforestry systems in Nigeria there is the need for a religious implementation of the Nigerian National Adaptation Strategy and Plan of Action and bringing to fruition the climate change commission of Nigeria that has been in the Nigerian parliament for some years now. Most importantly, climate change mitigation and adaptation should be properly institutionalized. Local adaptation efforts of the rural poor should be supported with livelihood option as they often have very limited diversification options available to them. Other factors heightening vulnerability to climate change and affecting national-level adaptation include issues of local and national governance, civil and political rights and low levels of literacy. In addition capital stock and extension advice, national grain reserves, grain future markets, weather insurance, food price subsidies, micro-financing and social welfare grants are just some of the tools that need to be used to enhance adaptation to climate change and mitigate impact of future shocks and stresses

The success of these mechanisms in overcoming such constraints according to IPCC (2014) can be enhanced if supported by local institutional arrangements developed on a long-term sustainable basis, mainstreamed into national development processes, with unprecedented collaborative efforts by governments, humanitarian and development agencies to find ways to move away from reliance on short-term emergency responses to food insecurity, to longer-term development-oriented strategies that involve closer partnerships with governments.

Despite the fact that Nigeria is not obliged under the current climate change mitigation framework to invest in climate change mitigation, it will be in the best interest of Nigeria to start its development drive by investing in energy friendly alternatives and more importantly invest its crude oil money in agriculture and forestry which are more enduring and sustainable. In doing this there is a need to provide effective adaptation to the sectors, such as investment in agroforestry and erosion control, adequate assistance and information to help farmers adjust their times of operation, early warnings, provision of energy cook stove to reduce wood fuel consumption, assist affected and vulnerable people in their relocation to safer places (migration), investing in irrigation facilities to boost dry season agriculture and in areas where rainfall is limiting, provision of subsidized inputs like farm equipment, fertilizers and agrochemicals, provision of adequate infrastructure; roads, water, electricity, health facilities and other social service which help to build resilience. Resonating from this DFID (2008) in their sustainable livelihood framework has identified investment in alternative livelihood initiatives for the vulnerable people in the society, support for social networks and cooperatives, provision of enabling political atmosphere, policies and frameworks as key for adaptations to bud and thrive. Also it is very important that with increasing globalization of markets Nigeria's competitive edge may be jeopardized if it fails to apply environmentally sensitive methods in its economic development. This *inter alia* will mean the pursuit of clean renewable energy alternatives (wind and solar) with which Nigeria is abundantly endowed. The interconnectedness of all these *inter alia* form part of the breakthroughs of this study as is shown in the resource use – climate change - conflict pathway model (Onyekuru and Marchant, 2014b). The model emphasize the linkages among the social, economic and environmental attributes of the society and how the inefficiency of the system predisposes vulnerable groups to conflict as a result of lack of adaptive capacity. On the other hand the ability of the system to effectively build the resilience of the citizenry is a sure way to, not only reduce tension and conflict among groups, but also create wealth and improve the livelihoods of the people.

Limitations of the research and areas for further research and improvement

One of the limitations of this research was the problem of resource – fund, time and personnel. It was very expensive to collect the primary data within the available time frame of three months; otherwise as much as 1000 respondents would have been sampled. In addition, getting seasoned enumerators who have the combined knowledge of the area climate change, agroforestry and understanding of the native languages of the respondents was a herculean task.

With respect to the survey design and data collections, it wasn't easy to achieve a perfect random sampling, due to financial and time limitations, since in some cases the required individuals were not on ground to be interviewed, refused to be interviewed or were indisposed and therefore has to be replaced with another person that is willing to participate. Nevertheless, efforts were made to get as much representative of the variations in the different ecological regions as possible that is required for the analysis. In addition variations in the understanding and interpretation of the concept of climate change from place to place, due to differences in language and literacy levels across zones; interviewers' and interviewees' bias were factors that may have play out in the analysis. Nevertheless efforts were made to harmonize such discrepancies by calling the respondents on their mobile numbers for clarifications in the cases of obvious deviations, before the analysis. Also the prior training of the research team, pretest of the questionnaire and constant monitoring and feedback from researchers while in the field were helpful in resolving some of these issues.

The use of net revenue instead of land value in the Ricardian analysis was a limitation as net revenues tend to reflect annual weather as it is difficult to estimate long term climate changes with annual revenue (Mendelsohn and Dinar, 2009). In the case of this analysis, net revenue is the most realistic approximation of land value, as in most cases land value are over estimated depending on their location (urban or rural) and therefore does not always reflect the actual value of the output of the land. Also since we are dealing with forest production, the outputs are so varied, spatially and temporally distributed in so many property right regimes that it is impossible to allocate any particular product(s) to any particular land unit.

Also the use of net revenue has been criticized for the problem of aggregation (Mendelsohn and Dinar, 2009), which is introduced because farm data that exist tend to aggregating annual yields over large terrains. In this analysis the problem was overcome by carrying out primary data collections which assigns prices to each specific sample unit in the analysis.

Also being a socioeconomic assessment, it was not possible for the Ricardian model to track impacts due to biophysical changes. Thus, the inference drawn from this study does not give the entire picture of the impact of climate change in the forest system.

There is therefore the need for further integrated assessment for a better understanding of biophysical dynamics of interactions of tropical forest and current and predicted climate change. This can be done by bringing together a multidisciplinary team of scholars under one umbrella, with each discipline looking at different aspects of the problem under a uniform framework and objective.

Nevertheless, the results offer useful insights to researchers, policy makers and development practitioners in their quest to understand the nature and magnitude of climate change impact in tropical forest systems and a wealth of idea about the nature and types of adaptation mechanisms, climate change perceptions and adoption process. These are very useful towards targeted policy interventions, especially in the areas of mitigation and adaptation planning in forest resource management.

Appendix 1: Questionnaire

Assessing Indigenous Adaptation Practices to the Impact of Climate Change on Forest Resources Use in Nigeria.

Questionnaire on Household

Introductory statement:

Scientific evidence have confirmed that the climate will likely change in the future with implications for agriculture and forestry. The information provided by you in this interview about your forest activities in the last 12 months will contribute to understanding the likely impacts of climate on the use of forest resources in Nigeria. Your responses to these questions are only for academic purpose and will be treated confidentially and anonymous. This study is a Ph.D research being conducted by Onyekuru N Anthony of the Department of Environment, University of York, UK.

Thank you for your kind co-operation.

Time interview started-------------------------------

1.0.1 Type of forest: ______ (KEY for 1.0.1: 1: Private ownership; 2: Community forest; 3 Government ownership; 4: Undefined common forest

1.0.2 Please state the relationship of the respondent to the household: ______-
Key for 1.0.2: Head of house hold, 2. Husband; Wife, 4: Child; 5: Grandchild; 6: Parents; 7: Siblings; 8: Other family members (including household helpers); 9: Manage

Section 1: Household Roster-Members of Households and Education
1.1 Household size: ________

1.2 Household Characteristics

	1.2.1. Gender	1.2.2. Age	1.2.3. Marital Status	1.2.4. Education (in No of yrs)	1.2.5. Work on Forest Activity?	1.2.6. Work on Non-Forest activities
1						
2						
3						
4						
5						
6						
7						
8						
	Key for 1.2.1: 1: Male; 2: female				Key for 1.2.5;1: yes; 2:no	Key for 1.2.6; 1:yes; 2: no

Key for 1.2.3: 1: Married or living together under local custom; 2: Never married; 3: Previously married, (divorced, separated, widowed); 4: Not applicable

Please use additional space on back of page if necessary.

1.3 Which tribe does the household head belong to? ______

1.4 What religion does the head of the household practice? _______ KEY for 1.4: 1. Nonreligious; 2; Christianity; 3. Islam; 4,African Traditional Religion; 5: other (pls. specify __________)

1.5 Does the household have electricity? __________ (KEY for 1.5: 1: yes; 2: no)

Section 2 Empowerment All questions pertain to the last 12 months

2.1	2.2	2.3	2.4	2.5.	2.6	2.7..
What is the primary occupation of the head of the household	What is the secondary occupation of the head of the household	Number of <u>Days</u> spent on primary occupation/week	Number of <u>weeks</u> over the last 12 months spent of primary occupation	Number of d<u>ays/</u>week spent on secondary occupation	Number of <u>weeks in</u> the last 12 months spent on secondary occupation	Number of work <u>Days</u> lost due to illness the last 12 months?

Key for 2.1 and 2.2: 1. Farmer 2. Agriculture (farm) laborers 3. Artisan 4.office worker 5. Civil servant 6. Teacher 7. Health worker 8. Trader 9. Student 10 Unemployed
11. Forest resource collection 12. Other non-agriculture worker . (One day of work= 6-8 hours of work.)

2.8: 7: if you collect forest products, how long have you been in the business? ________________ (in number of years)

Section 3 Tenures and labor composition All questions pertain to the last 12 months

3.1 How many separated land areas do you collect forest products? __________ (Interviewer; If response is "1", response to 3. 1a. 1 and 3. 1a. 4 only)
Key for 3.1:1: only 1 single area is farmed ; 2: 2 separate areas are farmed; 3:3 separate areas are farmed; 4:> 3 separate areas are farmed)

3. 1a. Please denote the total size of the forest land areas used over the last 12 months-------------------------------
3:1b Unit of measurement of land areas in 3.1a.1-3.1a.3 ______________________ (Ha, acres, etc. please specify)

Please answer the following forest use questions with respect to type of forest access by members of household:

3.1.1. Plot Numbers	3.2. Access to forest	3.3 Tenure type	3.4 How many (average) number of years have you used these plot?	3.5 Total rent paid (per Month) for using the forest
1				
2				

Key for 3.2: (1: Free access 2: Community regulate access 3: Government regulate access 4: Reserved area (access not allowed)

Key for 3.3: (1: own forest and own use 2: does not owe the forest)

3.4 Division of labor information by Activity for each season		3.4.2 Total Estimated Number of workers and days worked (per activity for each season) (1 day=6-8 hours of work completed by 1 individual).											
		Household labor						Hired labor					
3.4.1 Season and Type of Activity (specify the kinds of activity you do in the forest and who does what) e.g clearing, planting trees, pruning etc		3.4.2.1 Adult		3.4.2.2 Adult Female		3.4.2.3 Child (< 16 years)		3.4.3.1 Adult Male		3.4.3.2 Adult Male		3.4.3.3 Child (< 16 yrs	
		a. No.	b. Days	a. No	b. Days	a. No	b. Days	a. No	b. Days	a. No	b. Days	a. No	b. Days
season 1	11. clearing												
	12. planting												
	13. pruning												
	14. pesticide, fertilizer, irrigation, etc.												
	15. harvesting												
	16. post-harvest processing												
	17. other activities												
3.4.4	Crop production												
3.4.5	Livestock-animal management (annual estimate)												

3.5 Continues

3.5	Wage rates	Household labour			Hired labourer		
		Adult Male	Adult Female	Child	Adult	Adult	Child
3.5.1	Average wage/day (across various activities) for each type of worker	3.5.1a	3.5.1b	3.5.1c	3.5.1e	3.5.1f	3.5.1g
3.5.2	Total in kind payment per day (across various activities)	3.5.2a	3.5.2b	3.5.2c	3.5.2e	3.5.2f	3.5.2g

Section 4: Details on farming activities part1: food and tree crops All question to the last 12 months

4.1. Information on the primary products derived from the forest over the last 12 months.

Please use the following Key for 4.1.2: (if a crop is not listed below, please denote as ‘other’ and specify).

1. Alfalfa	11. Cocoyam	21. Grape	31. palm dates	41. Sesame	51. tef	61. honey
2. Banana	12. Cowpea	22. Ground nut	32. Paprika	42. Shallots	52. tobacco	62. rubber
3. Barley	13. Coffee	23. Kola	33. Peanuts	43. She nut	53. tomatoes	63. medicinal plants
4. Beans	14. Cotton	24. Lentil	34. Pepper	44. Sorghum	54. wheat	64. timber plants
5. Cashew	15. Cucumber	25. Mango	35. Pigeon pea	45. Soybean	55. yam	65 others (specify)
6. Cassava	16. enset	26. Maize	36. Pineapple	46. Spinach	56. rattan	66
7. Citrus fruit	17. Field pea	27. Millet	37. Plantain	47. squash	57. locus bean	67
8. Chickpeas	18. Flax	28. Oil palm	38. Potato	48. sugarcane	58. leafy vegetables	68
9. Clover	19. Garden-eggs	29. Okro	39. Rice	49. sunflower	59. bush meat	69
10. Cocoa	20. Garlic	30. Onion	40. Safflower	50. tea	60. mushroom	70

Output and revenue (Please use additional space If there are more than 6 products per plot)

4.1.1	4.1.2	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	4.9a	4.10	4.11	4.12b
s/n	Product Type (Use Key for 4.1.2 Above)	Planting Date (if planted by you)	Harvest Date	Proportion of plot area covered by product (%)	_Quantity Harvested (kg) (Includes Alertest	Amount Consumed by Household (kg)	Amount Consumed By livestock (kg)	Amount Lost due to disease/ Pests/ spoilage (kg)	Quantity Sold (kg)	To whom Out put sold?	Total Value of product sold (Farm-gate value)	Amount of Seeds/ seedling used for planting (kg)	Cost/kg of seed

Interviewer: please use additional space if necessary

Key for 4.9a: 1.Directly to consumers; 2. Middleman/wholesale establishment; 3. other

4.12 Please state the average quantity/yield of your 5 principle forest product in a normal month.

4.12.0.product Type (used code specified in 4.1)	4.12.1 Normal month Average Yield (in terms of kg/HA)	Unit price
Product 1		
Product 2		
Product 3		
Product 4		
Product 5		

KEY for 4.12.0 (if a product is not listed below, please denote as 'other' and specify).

4.14 Cost/kg of Fertilizer: ___________________________ 4.14 Cost/kg of Pesticide: ______________________

4.16: Information on equipment, Inputs and Buildings:

Tool/Machinery/Implements	4.16.1 Number	4.16.2 who owns the equipment?	4.16.3 Price (or value) unit	4.16.3a Average lifespan of item
Light tools:				
1. cutlass, machete				
2. hoe				
3. file				
4. axe				
5. baskets				
6. weeder				
7. others (specify				
Heavy Machinery				
8. sawing machine				
9. pressing machines				
10. trolley/trailers				
11. thresher				
12. fodder cutting machine				
13. generator/diesel pumps				
14. spraying machines (chem../fertilizer)				
15.others (specify)				
Animal Power				
16. bullocks				
17. mules				
18. others (specify)				
NB: for (7), (15) and (18), please specify each item information using additional spaces		KEY for 4.16.2: 1: household ownership; 2: jointly owned with household/farm entities 3: hired for household or joint use		

4.16.4 Please provide information on the buildings used to support production activities (table below)

4.16.4a Building No.	4.16.4b Purpose (Interviewer: please allow for multiple responses)	4.16.4c value
Building 1		
Building 2		
Building 3		
	Key for 4.16b; 1: space for storage of agriculture products; 2: space for processing products; 3: space for housing of workers; 4: space for storage of farm equipment ; 5: other uses	

4.17.1 How far is it to the nearest market where you sell you harvest? (a) In distance: _______ (kms); or (b) ______ in time (hrs)

4.17.2 What transport do you use to get to market? ____________________________

KEY for 4.17.2: Walk; 2: animal, 3 cart; 4. Truck or other motorized vehicle; 5. other (specify)

4.17.3 How far is it to the nearest market where you obtain your inputs? In distance: (a) ___________ (kms); or (b) ______________ in time (hrs)

4.20 Can you please tell us the total cost of the following activities?

Code	Type	4.20.1. Products	Code	Type	Products
1	Harvesting	4.201.1_____________________	2	Transport costs	4.201.2 ____________________
3	packing/marketing	4.201.3 ____________________	4.	Storage costs	4.201.4 ____________________
5	post harvest losses	4.201.5 ____________________	6.	Other (please specify) __________	4.201.6 ____________________

Section 5: Access and Extension Services All questions concern the last 12 months

5.1.0 Do you get information and advice from extension workers (Yes = 1, No = 2)	5.1.0a:
5.11 How many times do they visit you per year?	5.1.1a
5.12 Do you pay for receiving extension advice? KEY for 5.1.2: 1: yes; 2: no (if no, go to Q.5.1.4)	5.1.2a
5.13 How much do you pay annually for extension? _______	5.1.3a
5.14 The Extension officials who visit/contact you are from which organization?	5.1.4a
KEY for5.1.4: 1. Government Agency; 2. Agriculture research station; 3. NGO; 4. Other (specify)	KEY for 5.1.0: 1: yes; 2: no

5.2.1 Have extension officers provided information on expected rainfall and precipitation? KEY for 5.2:1: 1:yes; 2;no

5.3 If you get any technical assistance and advice from other sources apart from official extension workers, from where do you receive the necessary information? __________
KEY for 5.3: 1: Media; 2: Neighboring farmer, 3: Shopkeepers in village; 4: Others (please specify); 5: None

Section 6: Other Costs and Subsidies All question concern the last 12 months
6.1 What is the total household net income from forest activities (own or someone else's forest) in the last 12-months? ________________ (NB: use income table if necessary)
6.1.1 Over the last 12 months, what percent of total household is from non-forest activities (e.g. income (salary) from non-forest activities and other sources such as gifts, pensions, etc)? __________________________
6.2 What is the total net household income from forest activities in a normal average year? __________________ (NB: use income table if necessary)
6.2.1 In a normal average year; what percent of total household income is from non-forest activities (e.g. income (salary), artisanary and other sources such as gift, pensions, etc? ________________________

6.2 How much has your household paid for tax over the last 12 months?---------------------------
6.3 Did you borrow in the last 12 months? -------------------------------------- (1 : yes; 2 : No)
6.4 Did you borrow from any of the following sources for farming over the last 12 months

6.4.0 Source 6.4.1 6.4.2 6.4.3 6.4.4

Borrowed from: Repayment over how many

(1: yes; 2: no) Amount received Interest Rate/year Months/year

1. Relative/Friends 6.4.1.1 _______________ 6.4.2.1: _____________ 6.4.3.1: 6.4.4.1: ________________
2. Farmer associations/co-operative 6.4.1.2: ______________6.4.2.2 _____________ 6.4.3.2 6.4.4.3: ________________
3. Commercial banks 6.4.1.3: ______________6.4.2.3: _____________ 6.4.3.3: 6.4.4.4: ________________
4. Thrift and loan society 6.4.14 _______________6.4.2.4: _____________ 6.4.3.5: 6.4.4.5: ________________
5. Others (specify) 6.4.15: _______________ 6.4.2.5: _____________ 6.4.3.5: 6.4.4.5: ________________

6.5 Have you received any of the following types of subsidies during the last 12 months?

	6.5.1 (1: yes; 2: no)	6.5.2 Source	6.5.3 Amount/year
1. crop subsidy	6.5.1.1: _______________	6.5.2.1: ______________	6.5.3.1: _________________
2. input subsidy	6.5.12: _______________	6.5.2.2: ______________	6.5.3.2: _________________
3. Direct payment	6.5.13: _______________	6.5.2.3: ______________	6.5.3.3: _________________
4. Other (please specify type __________)	6.5.1.4: _______________	6.5.2.4: ______________	6.5.3.4: _________________

Key for 6.5.2: 1. From the government, 2. from NG; 3. from private sector sources; 4. From other (please specify sources)

Climate change impact

7.1 Have you noticed any long term shifts in the mean temperature in your area? (please explain) ---

----

7.2 Have you noticed any long term shifts in the mean rainfall in your area? (please explain)---

7.3 Forms of Climate Change Impact

Which of the following phenomena has impacted on your output in the past 10 to 30 years and to what extent do you agree that climate change is responsible for their occurrence.

Characteristics of phenomenon				Extent of agreement of cause by climate change				
Phenomenon	Yes :1	No:0	Year change began	Strongly agree	Agree	Don't know	Do not agree	Strongly disagree:
• Unusual early rains followed by weeks of dryness								
• Erratic rainfall pattern								
• Delay in the unset of rain								
• Long period dry season								
• Heavy and long period of rainfall								
• Less rainfall								
• No or reduced harmattan								
• Long period of harmattan								
• Higher temperature								
• Thunderstorms								
• Heavy winds								
• Floods and erosion								
• Drought								
• Desertification								
• Heat waves								
• Increase in pests problems								
• Uncertainties in the onset of farming season								
• High rate of disease incidence								
• Increase weed infestation								
• Loss of soil fertility								
• Drying up of streams/rivers								
• Overflowing of streams/rivers								
Others (specify)								

Adaptation Options

7.4 Have you done anything in the past to adapt to the impacts of climate change--------------- (1 : yes; 2 : no)

7.5 If you have, **other than your usual agronomic practices** what adaptation strategies has your household adopted **specifically for climate change impact** in your crop production and forest management: their costs and benefits (e.g. weather effects in terms of temperature and rainfall fluctuations, storms, etc) within and between season?

S/N	Adaptation practice	Area used		Positive impact (Naira)		Negative impact (Naira)	
		Crop	Forest	Added return	Reduced cost	Added cost	Reduced return
1	Purchase of water for irrigation						
2	Planting deeper or shallower than the usual planting dept						
3	Cultivation of more land area						
4	Increased weeding						
5	Water harvesting						
6	Planting of more trees to form shades						
7	Use of wet lands						
8	Increase use of fertilizer						
9	Use of resistant varieties						
10	Cultivation of marginal lands						
11	Migration or abandoning the site for another						
12	Erosion control						
13	Change from production to marketing						
14	Building shade						
15	Mulching						
16	Changing the times of farm activities						
17	Increased fallow period						
18	Multiple cropping						
19	Mixed farming (combining crop & animal production)						
20	Crop replacement/replanting						
21	Change from crop production to animal production						
22	Change to other businesses						
23	others specify						
24							
25							

7.6 What are the main primary constraints for making the necessary adjustments to climatic variation (for example weather effects in terms of temperature and rainfall fluctuation, wind, dust storms etc) within and between season?

S/N		Extent to which they affect you				
	Constraints	**Extremely serious**	**Very serious**	**Serious**	**Less serious**	**Not serious**
1	Limited availability of land for farming					
2	High cost of farm land					
3	Inherited system of land ownership					
4	Communal system of land ownership					
5	Non availability of credit facility					
6	High cost of irrigation facilities					
7	Non availability of storage & processing facilities					
8	Poor infrastructure					
9	High cost of fertilizers and other inputs					
10	Non availability of improved varieties					
11	Limited income					
12	High cost of labour					
13	Lack of access to weather forecast					
14	Poor access to information and extension agents					
15	Inadequate knowledge of how to cope					
16	Traditional beliefs/practices					
17	others specify					
18						
19						

This section must be completed after the interview is completed. Given the importance of the following data for mapping and tracking purposes, please ensue it is filled accurately.

Instructions: This section to be filled out by interviewer.

Time Interview Ended: _________________

Name of interviewer: ___________________________ (this information is important to validate survey responses and will be used to cross check in the event that there are

Unusual observation during the analysis of the data)

Date of interview -- Time Interview Began: ___________________________

Agricultural zone Code: ------------------------------ Name of town and village --

Household name (optional) _____________________ Optional: Contact information of Respondent:

____

Monthly Income of Household Head--------------------

Phone --- (Address)

____

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