Sector Network Rural Development, Africa

ENHANCING ADAPTATION OF FORESTS AND PEOPLE IN AFRICA

Development of Pilot Cases for Selected Forest Ecosystems in Ghana and Malawi

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Acronyms and Abbreviations

ANR	Assisted Natural Regeneration
BEST	Biomass Energy Strategy
CFC	Community Forestry Committee
COMPASS	Community Participation for Action in the Social Sector
CPF	Collaborative Partnership on Forests (United Nations Forum on Forests)
DANIDA	Danish International Development Agency
DFID	Department for International Development
DRC	Democratic Republic of Congo
EAD	Environmental Affairs Department
ENSO	El Nino Southern Oscillation
FAO	Food and Agriculture Organization
FORIG	Forest Research Institute of Ghana
FORNESSA	Forestry Research Networks of Sub-Saharan Africa
FRIM	Forestry Research Institute of Malawi
GCM	General Circulation Models
GFEP	Global Forest Experts Panel
GHG	Green House Gases
GIZ	German Agency for International Cooperation (former GTZ)
GoM	Government of Malawi
INCM	Initial National Communication of Malawi
IPCC	Intergovernmental Panel on Climate Change
ISSER	Institute of Statistical Social and Economic Research (University of Ghana)
ITCZ	Inter Tropical Conversion Zone
IUFRO	International Union of Forest Research Organizations
LCC	Lake Chilwa Catchment
NAPA	National Adaptation Programmes of Actions
NFP	National Forestry Programme
NLBI	Non-Legally Binding Instruments on Forests
NTFP	Non-Timber Forest Products
NTPP	National Tree Planting Programme
PES	Payment for Ecosystem Services
REDD	Reduced Emissions from Deforestation and Forest Degradation
SCM	Simple Climate Models
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
VNRMC	Village Natural Resource Management Committee

UNDP United Nations Development Programme
VNRMC Village Natural Resource Management Committee

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Executive Summary

Commissioned by the Sector Network Rural Development of GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH on behalf of the Federal Ministry of Economic Cooperation and Development), forest scientists of the Forestry Research Network of Sub-Saharan Africa (FORNESSA) conducted the present study on adaptation of forests and people to climate change at two localities in Ghana and Malawi, respectively. The objective of the study (Section 2) was to identify elements of adaptation strategies in order to define concrete, resilient adaptation measures that can be implemented on the ground within the selected pilot areas. These and the applied methodological approach may serve as guidance and recommendation for the development of adaptation projects in Africa.

The selected pilot area in Ghana (West Africa) is situated in the High Forest Zone (tropical high and transition forests) representing a heavily degraded savannah landscape while the pilot site in Malawi (Southern Africa) is dominated by an agricultural landscape with highly degraded watershed protection forests. Both areas represent typical examples of the ecological and socio-economic situation prevalent in the region.

The methodology applied in this study (Section 3) is based on a three-tiered approach involving (a) a **global assessment** of adaptation of forest and people to climate change conducted by IUFRO; (b) an **African assessment** of the latest science available on climate change and its impacts on forests and people in Africa; and (c) the **development of concrete adaptation measures for a specific project site** based on a detailed assessment and evaluation by means of compilation of existing information and consultations with local communities, followed by a priority setting exercise for identifying adaptation strategies and activities.

Section 4 of this report provides information on the two pilot areas including geographic location, ecological conditions, socio-economic situation, and current pressures on the natural resources. These pressures have resulted in large-scale environmental degradation, including soil erosion, loss of forest area, and significant reduction in the provision of important goods and services from forests and trees.

The study then analyses available data on the trends in local climate parameters over the past decades such as temperature and precipitation (Section 5). From this analysis it is evident that there are observable changes in local climate in both pilot areas. These climatic changes in combination with past and present land-use practices have negative impacts on ecosystem functioning and productivity. These effects are clearly visible as various levels of resource degradation.

The most pressing issues related to resource degradation are described for each pilot area in more detail in Section 6. Major aspects addressed include forest losses due to wildfire, decline in the availability of non-timber forest products, poor productivity of trees on farm, loss of indigenous tree species, reduction in agricultural crop yields, decline in fish catch, and declining potable water supply and the associated risk of water-borne diseases. The section concludes with a summary table for each pilot area linking priority issues related to resource degradation and associated vulnerabilities described in this section with appropriate adaptation measures outlined in greater detail in Section 7 and 8. The two tables are intended to highlight the fact that designing meaningful adaptation projects on the ground is about setting priorities involving the selection of a few but most effective adaptation measures.

In Section 7 and 8 adaptation measures are presented separately for each pilot area. The outline is structured according to the priority issues explained in Section 6. For each priority issue past and ongoing adaptation measures are described, followed by new measures to be undertaken, in order to better cope with the consequences of resource degradation and/or reduce or even reverse such degradation. These adaptation measures are presented in tabulated format linking them to key vulnerabilities identified earlier in the analysis. In this way, the rationale for recommending a particular adaptation measure is highlighted.

Finally, in Section 9 a summary is provided on lessons learned in conducting this study and working through the process of developing adaptation measures and strategies for specific local situations. These lessons learned are intended to contribute towards developing appropriate standards for designing adaptation projects.

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) has presented clear evidence that the climate is changing and that the emission of greenhouse gases is the main driver of that change (IPCC, 2007). The growing levels of carbon dioxide (CO_2) and other greenhouse gases (GHG) in the atmosphere as a result of human activities are directly and unequivocally linked with changes in the global climate (Hulme and Murphree*,* 2001; IPCC, 2007). Global climate change is expressed through an increase in recorded temperatures, changes in rainfall, glacial melt and an increase in the incidence of extreme climatic events (IPCC, 2007). The extent to which societies reduce their greenhouse gas emissions ('mitigation') will affect the scale of future change. However, regardless of climate change mitigation measures taken today or in the near future, historical emissions and inertia in the climate system mean that further climate change is inevitable (Karl and Trenberth, 2003).

IPCC (2007) reported that Africa is particularly vulnerable and will be struck more severely by climate change than any other continent of the world because there, the capacity to adapt to climate change is limited considerably by widespread poverty (Hulme and Murphree*,* 2001). The African people and African ecosystems with their unique biodiversity will be the major victims of climate change and vulnerability (Unmüßig and Cramer*,* 2008).

Many regions in Africa are already experiencing unprecedented climate change, and many people are suffering more and more from changes in rainfall patterns, unexpected droughts, and resulting changes in ecosystems which provide for their livelihoods (Transer *et al.,* 2003 Thomson *et al.,* 2004; IPCC, 2007; Hendrix and Glaser, 2007). The forest ecosystem for instance, which is considered as a socio-ecological system, provides essential goods and services which support the well-being of most people in Africa (Idinoba *et al.,* 2009). Large parts of the continent are recognised as having climates that are variable and complex (UNFCCC, 2007). This and the widespread lack of reliable data make it a real challenge to predict climate change and its impact on forests and people.

Following IPCC (2007), rainfall is projected to decrease in western and winter rainfall areas of southern Africa, but to increase in the east. Projections for the Sahel and the Guinea coast are uncertain, as the global climate models are unreliable in this region. Climate change impacts for the African continent are generally based on predictions from General Circulation Models (GCM) and Simple Climate Models (SCM). Differing climate projections and model uncertainties present serious challenges when determining potential changes with regard to niches of species that are only adapted to particular forest ecosystems. Successful adaptation will become a prerequisite for the well-being of African people and for reducing emissions from and enhancing carbon stock in forests. Therefore, capacity development for adaptation will become an essential element of German cooperation, especially in the framework of sustainable management of natural resources.

In 2007 the Collaborative Partnership on Forests (CPF) established the CPF Global Forest Expert Panels initiative GFEP as a mechanism for providing policy and decision makers with up-to-date scientific information. GFEP provides objective and independent scientific assessments of existing information about key issues of global concern. It is a key principle of GFEP not to carry out new research, but to assess existing information.

In April 2009, GFEP, coordinated by IUFRO, published the first global assessment report "Adaptation of Forests and People to Climate Change". The report presented the state of knowledge regarding the impacts of climate change on forests, the socio-economic implications and the options for adaptation. It was prepared by an Expert Panel consisting of 37 scientists from different forest-related disciplines and from different parts of the world.

The assessment presented clear scientific evidence about climate change impacts on forests and people and sounded an alarm for policy makers about the pressing need for adaptation. It also indicated that the amount and quality of globally available scientific information varies significantly among regions. The report stipulated that more needed to be known in particular about the impacts on forest ecosystems in Africa and possible adaptation options that would work under the prevailing socio-economic circumstances.

As a consequence, IUFRO was tasked with a follow-up project. The main objective of the project was to support national and regional adaptation in Africa by encouraging improved scientific understanding of the impacts of climate change on forests and people in Africa and focussing on options and priorities for adaptation. More specifically, the project has produced:

- a regional analysis (i.e. scientific interim report) on the adaptation of forests and forest management to climate change, published in August 2010; and
- a summary on the subject for policy makers (policy brief) for regional and national decision-making, published in May 2010.

The seven key messages of the African Policy Brief (Kleine, *et al*. 2010) present general statements about possible adaptation measures; however, since situations differ across the continent, it is necessary to develop more appropriate actions that suit specific local conditions. Therefore, the adaptation strategies proposed in this report were developed to model specific situations in two pilot cases, one in Ghana and the other one in Malawi.

2. Objectives

As a sequel to the global assessment on adaptation of forests to climate change and the regional analysis of adaptation measures in Sub-Saharan Africa, this study represents the final step of a three-tiered approach to developing adaptation strategies for effective implementation on the ground.

2.1 Objectives of the study

The objective of the present study is to identify elements of adaptation strategies in order to define concrete, resilient adaptation measures that can be implemented on the ground in the selected pilot cases. These and the applied methodological approach may serve as guidance and recommendation for the development of similar adaptation projects in Africa.

The following localities representing tropical high and transition forests in West Africa, as well as Miombo Woodlands in Eastern and Southern Africa, were selected as sites for the pilot cases:

- Offinso District in Northwestern Ghana located in the Moist Semi-deciduous (MSD) forest type of the High Forest Zone of Ghana, and today representing a heavily degraded savannah landscape; and
- Lake Chilwa Catchment in the Southeast of Malawi, bordering Mozambique, representing an agricultural landscape with highly degraded watershed protection forests.

2.2 Justification for the selection of the pilot cases

Offinso District in Northwestern Ghana

For most communities in the Offinso District, the forest represents their primary source of food, income and security (Wagner and Cobbinah, 1993; Appiah *et al.,* 2009). The forests in the area provide many timber and non-timber products like snail, bushmeat, fuelwood, and medicinal plants and also ensure the maintenance of soil fertility and protection of watersheds (Appiah *et al.,* 2009; Hapsari, 2010). Despite this critical role, the structure and function of the forests have been influenced by continual pressure from human-induced activities (Blay, 2004). In the past, the Offinso area was classified as lying within the moist semi-deciduous forest zone, but heavy timber exploitation, frequent wildfire incidences, and unsustainable agricultural practices through shifting cultivation have led to high levels of deforestation and forest degradation in the district (Hawthorne and Abu-Juam, 1993; Appiah *et al.,* 2009).

The Offinso District represents one of the most fire-prone areas in Ghana’s forest zone, characterized by frequent annual bushfires. Due to the degraded nature of the forests, the conditions favour colonisation of large portions of the vegetation with woody alien invasive species, *Broussonetia papyrifera* (Paper mulberry) (Bosu and Apetorgbor, 2007) and *Chromolaena odorata*.

Since these disturbances of the forest ecosystem have occurred over long periods of time, it is unlikely that any type of mitigation actions would bring about a sudden reversal to the previous state. Indeed, as likely as not any reversal would span another generation or more. The current changes have made the local people vulnerable, and although efforts are made to alleviate the impacts, the effects are still devastating. Therefore, appropriate adaptation strategies are needed to enable the local people to cope with the impacts on their livelihood and well-being, while efforts are made to restore the degraded forests.

Lake Chilwa Catchment in Malawi

The Lake Chilwa Catchment belongs to the Miombo woodlands and is one of the most extensive dry forest vegetation types in Africa, occurring in eleven countries in eastern, central and southern Africa; namely Angola, Botswana, Burundi, Democratic Republic of Congo (DRC), Malawi, Mozambique, Namibia, South Africa, Tanzania, Zambia and Zimbabwe (Chundama, 2009).

The catchment is also a major agricultural ground, which includes crop-growing activities and small-scale organized rice schemes in existing wetland areas. The main crops grown in the wetland are maize and rice, depending on the location, and approximately 92% of the people in the wetland grow crops. The agricultural production is exclusively small-scale farming, using traditional methods of agricultural production. The forest resources are mainly restricted on the mountainous areas of Zomba-Malosa which extend into the Liwonde forest reserves. The woodlands are very important to the livelihoods of approximately 100 million people in the miombo ecoregion through the provision of wood and non-timber products (Campbell *et al.*, 2007).

3. Methodology

Understanding the fundamental properties of the atmosphere and their interactions with natural and human systems on earth has for long been the focus of scientific inquiry. However, because of the complex nature of the subject and the scarcity of data in many parts of the world, climate-related research including forest research has always been fragmented, addressing specific issues at various scales. Only recently, considerable investments have been made in bringing together the wealth of data and past research results and using them for predicting future climate change and its impacts on the earth's systems (e.g., IPCC Reports). Obviously, most of the results are useful at the global and regional scales, only a few appear to be suitable at sub-regional levels. Given the fact that adaptation measures to be pursued on the ground largely depend on some form of estimations of future climate change trends, the following three-tiered approach has been employed by IUFRO and FORNESSA:

- Level 1: Global Assessment on "Adaptation of Forests to Climate Change"
- Level 2: Regional Assessment on "Making African Forests Fit for Climate Change"
- Level 3: Elaboration of Adaptation Measures at Project Level

3.1 Global assessment

As discussed in the introduction above, a global assessment of the adaptation of forests to climate change has been conducted by the IUFRO-led CPF Initiative on "Global Forest Expert Panels." The work which was completed in early 2009, involved the following major steps:

Step 1: Literature Reviews

In order to avoid duplication of work, the conceptual frameworks of two major global assessments (i.e. Millennium Ecosystems Assessment and IPCC Report 2007) were analysed. The results assisted in structuring the global forest assessment report (Kleine and Roberts, 2007). Further literature reviews were regularly undertaken as part of the work of the Expert Panel as described in the following step.

Step 2: Expert Panel

The expert panel was headed by a Panel Chair, who worked as overall coordinator and main editor of the assessment report. The members of the panel served as Lead Authors for the various chapters of the assessment report. They were assisted by Contributing Authors providing further input, particularly from the various regions and sub-regions. In total, 35 scientists of various specialisations worked for about 18 months and compiled the relevant information and prepared the draft assessment report. Besides intensive email and telephone conversations, two face-to-face meetings were held, one for reconciling the scientific report and the other one for elaborating the key messages for the policy brief.

Step 3: External Review

Following the completion of the draft scientific report and policy brief, an evaluation was conducted by several external reviewers providing comments and further input in terms of additional research, references, and editorial aspects. This external review was a critical step providing the opportunity to countercheck the information and conclusion drawn in the assessment. As a result, the Global Assessment Report and Policy Brief were structured according to the following main chapters:

- Interrelation between forest ecosystems and services provided by them, and the climate;
- Observed changes and responses in forest ecosystems to climate change;
- Threats and likely future impacts of climate change on forest ecosystems and socio-economic impacts on the forest sector;
- Adaptation practices, options, constraints and capacity.

3.2 African assessment

Building on the Global Assessment a group of forest scientists specialised in forests and climate change under the Forestry Research Network of Sub-Saharan Africa (FORNESSA) elaborated a regional scientific report and policy brief titled "Making African Forests Fit for Climate Change". The work was facilitated by the IUFRO Headquarters with support from a research scientist of the University of Natural Resources and Life Sciences, Vienna, Austria. The process involved the *following steps:*

Step 1: Literature Review

Review of 250 scientific publications (in addition to the forest-related literature contained in the global assessment) addressing climate change issues in all its dimensions in the African context.

Step 2: FORNESSA Thematic Group on Forests and Climate Change

This expert panel consisted of African scientists from the major African regions. The work was guided by the structure of the global assessment, taking into account the specific ecosystems and socio-economic circumstances found in Sub-Saharan Africa. Results were compiled in a scientific report titled "Climate Change Impacts on African Forests and People" (Eastaugh *et al*. 2009).

Step 3: Key Policy Messages

The expert panel continued its work with a three-day face-to-face meeting aimed at formulating key policy messages derived from the information contained in the scientific report. In total 7 key policy messages were identified and provided the basis for developing a policy brief. This policy brief explains the policy messages by further elaborating on why African forests matter; how climate change affects forests and people in Africa; and what adaptation options are considered suitable in the African context.

3.3 Elaboration of adaptation measures at the local (project) level

Following the preparation of the Global and Regional Scientific Reports on Climate Change it was considered expedient to develop adaptation strategies on pilot scales in two pilot areas. The processes involved are discussed below.

Step 1: Selection of two pilot areas

- Offinso District in Northwestern Ghana located in the Moist Semi-deciduous (MSD) forest type of the High Forest Zone of Ghana today representing a heavily degraded savannah landscape.
- Lake Chilwa Catchment Area in the Southeast of Malawi, bordering Mozambique, representing an agricultural landscape with highly degraded watershed protection forest.

Step 2: Expert Groups

Given the broad nature of the adaptation issues at stake, it was necessary to tap expertise from as broad a range of disciplines as practicable. Accordingly, two expert groups were formed, one for each pilot case (Ghana and Malawi). The expert group from Ghana was composed of the following members:

- Dr. Ernest Foli (Silviculturist & Forest Management Specialist/Team Leader);
- Dr. (Mrs.) Beatrice Obiri-Darko (Socio-Economist/Agro-Economist);
- Dr. Dominic Blay (Jr). (Ecologist & Forest Landscape Restoration Specialist);
- Dr. Victor K. Agyeman (Ecophysiologist/Forest Management Specialist);
- Mr. Shalom Daniel Addo-Danso (Forest Ecologist);
- Mr. Francis K. Dwomoh (Remote Sensing/GIS Specialist).

The expert group from Malawi was composed of the following members:

- Dr. Steve Makungwa (Forest Mensurationist & Team Leader)
- Dr. Clement Chilima (Forest Entomologist)
- Mr. Henry Utila (Forest Ecology & Climate Change Specialist).

Step 3: Compiling of information

This aspect of the work entailed the following activities:

- Identifying and analysing all existing work and/or published information on climate change variability and its impacts in the area.
- Identifying the gaps that exist in the existing/on-going climate change adaptation initiatives.
- Identifying existing local knowledge about resource depletion related to climate change and other human-related factors, as well as the traditional/local strategies in place to adapt to the observed impacts, through focus group discussions and stakeholder consultations.

Specifically, the experts compiled relevant information about the pilot areas regarding the following aspects:

- Brief description of the forest ecosystem, eco-region;
- Local trends in climate change (historical records);
- Current vulnerabilities and future climate change trends;
- Current knowledge on adaptation to climate change.

Step 4: Consultation with communities

The communities including field forest officers and local NGOs were consulted in focus groups to discuss the problems they are facing in the area as a consequence of changing climate, the locally-devised strategies they have adopted in combating and/or adjusting to these climate-induced impacts on the environment and their own livelihoods and well-being, and to devise appropriate science-based adaptation strategies to mollify the severity of the impacts.

Step 5: Priority setting for adaptation strategies and activities

Generally, given the very many options and strategies that exist for dealing with adaptation to climate change and other human induced impacts, it is important to identify the options available, to prioritize them, and to select the most suitable approach to dealing with the problem within the context of specific local conditions. This type of priority setting should be guided by the following principles:

(1) The need to develop appropriate evidence-based, concrete adaptation strategies and related activities.

(2) The need to avoid unwarranted duplication of efforts by building on existing initiatives so as to improve the effectiveness of past and ongoing adaptation measures.

(3) The need to build resilient societies, resilient ecosystems that are more adaptable to changing climates, as well as other tangible and intangible benefits. These should be reflected in improved socio-economic circumstances, increases in productivity, reduced soil erosion, etc.

(4) The need to prioritize the observed impacts by consensus with the local communities and relevant stakeholders in order to determine the most important impacts of climate change and resource depletion for the communities' livelihood and well-being.

(5) The adaptation measures considered should not be confined to forest and tree-related issues only, but should include all other sectors, e.g., agriculture, water and sanitation, health, etc.

In the specific case of the Offinso District in Ghana, this aspect was based on earlier work (Bosu, *et al.*, 2010) carried out in the district by scientists from FORIG, who are also members of FORNESSA's Thematic Group on Forests & Climate Change. The earlier work sought to (1) assess the impact of climate change in the Offinso District, (2) determine the coping and adaptation strategies adopted by the communities to overcome climate change impacts, and (3) establish baselines for future research and development of climate change adaptation strategies.

The adaptation strategies and activities in the present study derive mainly from the earlier work above (Bosu *et al.*, 2010) and the key impacts of resource depletion as a consequence of the variability in climate and climate change in the district. The impacts of climate change identified by the communities and other stakeholders from that previous study were discussed and prioritized by the present team into four major impacts. Then, based on the existing adaptation strategies devised by the communities, concrete science-based adaptation strategies and activities were developed.

In the Lake Chilwa Catchment of Malawi, this study was built on the work that was done under the DANIDA-funded Lake Chilwa Wetland and Catchment Management Project which produced baseline data and a management plan, but ended in 2001. Realising that the problems found in Lake Chilwa Catchment (poor soil fertility, severe land pressure, population growth and density, widespread poverty) are representative for all of Malawi, we networked with other climate change and environmental management projects across the country. These included the community-based work of the on-going EU-funded 'Improved Forest Management for Sustainable Livelihoods Programme' which is targeting Zomba-Malosa and Liwonde catchment areas, and the USAID funded COMPASS program which promoted community-based natural resource management throughout Malawi as well as specific climate change projects being carried out by the World Bank and FAO, Total Land Care, Malawi Red Cross and a DFID funded LEAD work on climate change perceptions and coping strategies.

4. Description of the Pilot Cases

4.1 Offinso District, Ghana

4.1.1 Location

The Offinso District of Ghana is located in the extreme north-western part of the Ashanti Region at 6° 48'N and 1° 38'W.

4.1.2 Ecological region

In the 1950's the Offinso area was classified as lying within the Moist Semi-deciduous (MSD) forest type of the High Forest Zone of Ghana (Figure 1), characterized by high forest tree species of high economic value such as *Milicia exelsa*, *Antiaris toxicaria*, Celtis spp., *Triplochiton scleroxylon*, Entandrophragma spp., Khaya spp, *Nauclea diderrichii*, *Pericopsis elata*, *Terminalia ivorensis, Guarea cedrata,* and others. However, owing to forest degradation over the years, it is currently classified as a forest-savannah transition in the Dry-Semi deciduous Fire Zone (DSFZ) of Ghana. It is now characterized by sparse woody understorey and few scattered remnant dominant or canopy trees of the original high forest, except for the forest reserves, although they have also suffered degradation from human population-induced pressure, and the economic timber tree species are now scarce.

The district has semi-equatorial conventional climate with two rainfall seasons. The major rains occur in April to July, while the minor season lasts from September till mid-November. Annual rainfall ranges from 1,500 mm in the north to 1,700 mm in the south, with a mean monthly temperature of 27°C. The area is drained by two major streams, the Afram which is located in the east, and Brimu in the west. There are, however, several other largely ephemeral water bodies.

The forests and their resources continue to form an integral part of Ghana's natural heritage. These forests are unique due to several reasons: structural complexity, genetically endowed, highly productive and diversified into different subtypes (Hall and Swaine, 1976). The Offinso District which is classified as forest-savannah transition lies within the dry semi-deciduous forest fire zone subtype (Hall and Swaine, 1981), and has eight forest reserves (UNDP, 2007a). The forests in the district are characterised by sparse woody understorey and few scattered remnant dominant trees of the original high forest. The light canopy in these forests has increased the presence of ground flora, including *Marantaceae* spp. and *Zingiberaceae* spp. (Swaine *et al.,* 1997). The area is composed of tree species of economic value such as *Milicia excelsa*, *Antiaris toxicaria*, *Triplochiton scleroxylon*, *Khaya* spp., *Entandrophragma* spp., *Guarea cedrata* which continue to generate substantial revenue for both national and local economies, although over the years volumes have declined as a result of over-exploitation, fire and illegal timber harvesting.

4.1.3 Socio-economic situation and pressure on the resources

The Offinso District has a population of 138,500, with a density of 63 persons per km^2. The economically active population comprises the 15 – 64 years age group, which constitutes about 49% of the total population. Agriculture, which engages more than 70% of the economically active population, remains the mainstay of the District's economy in terms of employment and income generation, and contributes about 55% from food crops, 35% from cash crops and 10% from livestock to the household income in the District. The major food crops produced in the District are plantain, cassava, yams, cocoyam and maize, and a total land area of about 24,000 hectares is put under food crop production each year. Vegetables such as tomatoes, peppers, garden eggs, and okra are also produced and are mostly grown in Akomadan, Afrancho, Nkenkaasu, Asuoso and surrounding areas. Cocoa, oil palm, and citrus are the main cash crops produced in the District. It is estimated that about 23,500 hectares of farmland lie fallow each year as a result of unsustainable agricultural practices and shifting cultivation.

Figure 1: Vegetation map of Ghana showing Offinso District in red circle (Source: IUCN, 2009)

The main pressure on the forest resources derives from increasing populations and the need for more land for agricultural production. This is exacerbated by unsustainable agricultural practices through shifting cultivation, regular occurrence of forest fires, over-exploitation of timber, illegal timber harvesting, and encroachment by migrant farmers as a consequence of changing climatic conditions. Crop failure as a result of changing rainfall patterns and drought has also increased the rate of encroachment on the forest as the demand for more fertile land increases each year.

Over the years, this situation has gradually impacted on the structure of the forest and its capacity to continue to provide the ecosystem services that the communities derive from it. In effect, it is becoming increasingly difficult for farmers to plan cropping seasons to coincide with the rains in order to maximize crop yield, as rainfall patterns have become increasingly unpredictable. Along with the unreliable rainfall regime, increasing temperatures and more intense and prolonged sunshine result in the wilting of cocoa leaves and poor yield of vegetables and other crops. Therefore, in addition to the disruption of the community livelihood as a result of low agricultural output, heat and water stress related diseases such as malaria, diarrhoea, bilharzias, shingles and other skin conditions are also becoming more common. The result is increasing poverty and upsetting community well-being in the District; it is thus important to devise appropriate strategies for coping and/or adapting to these effects.

4.2 Lake Chilwa Catchment, Malawi

4.2.1 Location

The Lake Chilwa Catchment lies in a tectonic depression in south-eastern Malawi at 15°00'S latitude and 35°30'E longitude (Figure 2). The catchment is bounded by the Zomba Mountain to the west, the Mulanje Massif to the south and the Chikala Hills to the north.

4.2.2 Ecological region

Lake Chilwa Catchment is made up of a shallow, enclosed endorheic saline lake, surrounded by an area of dense *Typha* swamps and marshes. The seasonally inundated grassland floodplain forms a belt around the marshes of the lake, which extend into the intensively cultivated land areas bounded by the Zomba Mountain, the Mulanje Massif and the Chikala Hills. The swamps, mashes and the floodplains are dominated by grasses of the genus *Hyparrhenia, Cyperus* and *Diplachne.* The cultivated areas were previously dominated by the miombo woodland species of *Brachystegia*, either alone or with *Julbernardia* (White, 1983). The cultivated land has some residual miombo species standing, whereas the forest reserves surrounding the catchment have typical miombo characterisation. Miombo is an open park-like layer of big and often twisted trees with pinnate leaves and Y-shaped branching in a luxuriant grassy field layer (Kielland-Lund, 1982). The woodlands are very important to the livelihoods of the inhabitants of the catchment for the provision of wood and non-wood products (Maloya, 2001).

The Lake Chilwa Catchment is very rich in natural resources and, if put to sustainable use, these resources are of economic benefit not only to the people in the catchment but to the entire Malawi. To this effect, the Malawi Government ratified an international treaty on wetlands, the Ramsar Convention, in 1997, and listed Lake Chilwa as wetland of international importance. The government of Malawi is thus obliged to ensure that the use of resources by humans in the wetland is done wisely, i.e. in a manner that would yield the greatest and continuous benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations.

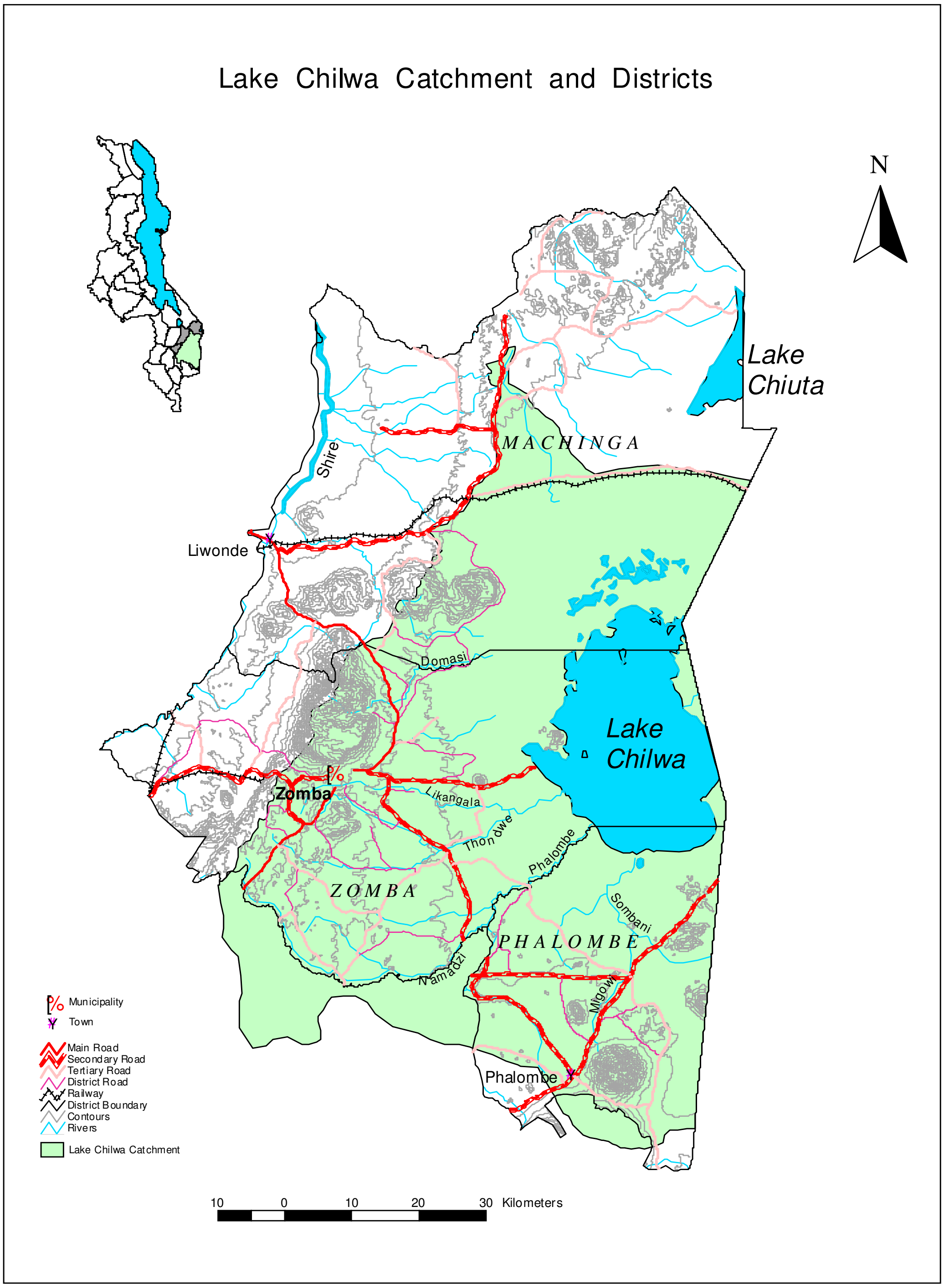

Figure 2: Geographical location of Lake Chilwa Catchment

4.2.3 Socio-economic situation and pressure on the resources

The catchment is one of the most densely populated areas with an estimated 1.3 million people and a population density of 164 people per km^2 (National Statistical Office, 2008). Over 60% of the population depends on subsistence farming for their livelihoods together with petty trading and fishing. Approximately 75% of the farming population has less than one hectare on which to cultivate and to support an average family size of 6 people (National Statistical Office, 2008). According to the Lake Chilwa Wetland State of the Environment Report (2000), 90% of all households in the catchment are short of food by the end of February every year. This figure is a telling indicator of the poverty and vulnerability of the people in the catchment.

Degradation in the upper catchment, including deforestation and forest degradation, poor agricultural practices and lack of soil erosion control and steep slope cultivation affect the livelihoods of all catchment residents. These practices have led to increased silt loads in the rivers during heavy rains, which in turn led to further loss of topsoil and a decline in agricultural yields. Silt loads affect irrigation downstream and ultimately the siltation of the Lake Chilwa itself, which is of significant importance to the local economy and nutrition. Van Zweiten and Njaya (2003) estimated that the Lake Chilwa contributes between 16% and 43% to the total fish catch of Malawi.

Because of the interdependence between water, forestry, agriculture, fisheries and ancillary activities and the complimentary flux of income and labour between farming and fishing, the catchment provides a unique microcosm for developing and implementing multi-scale adaptation strategies relating to climate change impacts going beyond the forestry sector. Past livelihood and ecological studies on the catchment provide clear evidence that the Lake Chilwa Catchment constitutes a fragile ecosystem due to extreme pressure from deforestation, forest degradation and fires in its catchment, as well as the periodic complete desiccation of the lake on several occasions in the past. The interplay of population induced pressure and climate change clearly calls for a holistic approach to adaptation strategies which this case study intends to address.

5. Local Trends in Climate Change

5.1 Offinso District, Ghana

The Offinso District is characterised by a semi-equatorial and tropical conventional climate. The area receives annual rainfall ranging from 1,250 mm in the north to 1,500 mm in the south, and mean monthly rainfall ranges from below 30 mm to about 200 mm. There are two rainfall seasons. The major season occurs from April to July with a short dry season in August. The minor season begins in September and ends in mid-November with a long dry season between December and March.

Daily mean minimum and maximum temperatures range between 22ºC and 30ºC respectively, although maximum daily temperature can reach as high as 35ºC during the hottest months in the dry season. Past and present climatic conditions indicate symptoms of climate variability (Table 1) for the ecological zone (Gyampoh *et al.*, 2007), with consequences on livelihoods (Amisah *et al.,* 2009) and forest ecosystems (Dixon *et al.,* 1996). Studies show that climatic conditions in the dry semi-deciduous forest zone may be changing and becoming more unpredictable (Nelson and Agbey, 2005; EPA, 2008). The Offinso District in particular has been experiencing unprecedented extreme weather conditions, such as increased temperatures and unpredictable rainfall patterns (Gyampoh *et al.,* 2007; Amisah *et al*., 2009).

Ecological Zone	Temperature (°C)				
	1960	**1970**	**1980**	**1990**	**2000**
Rainforest	26.5	26.3	26.5	26.4	26.8
Deciduous forest	26.5	26.2	26.3	26.7	26.9
Coastal Savannah	27.0	27.3	27.0	27.1	27.7
Transitional Zone	26.8	27.0	26.9	27.3	27.3
Guinea Savannah	27.2	27.8	27.8	28.2	27.8
Sudan Savannah	28.1	28.8	29.2	29.2	29.0

Table 1: Mean annual temperatures (1960–2000) for six ecological zones in Ghana (Adapted from Nelson and Agbey, 2005)

5.1.1 Temperature trends

There is evidence to suggest a general increase in surface air temperatures for Ghana (EPA, 2000) and the Offinso District in particularly (Amisah *et al.,* 2009). Agyemang-Bonsu (2006) indicated that there has been observed an increase in temperatures of about 1ºC over a 30-year period for the entire country. Studies by Amisah *et al.,* 2009 in the Offin basin, of which Offinso District is a part (UNDP, 2007) showed a gradual increase in mean maximum temperatures from 30.2 ºC in 1961 to 31.51 ºC in 2006, representing an increase of 1.31ºC (or 4.3%) during that period (Figure1). This average rise is even greater than the national rise in temperature of 1ºC (Agyemang-Bonsu, 2006).

The mean minimum air temperature also followed a similar pattern, starting with a mean annual temperature of 21.1ºC in 1961 to 22.1ºC in 2006. This suggests that the basin has been experiencing gradual, but steady rise in temperatures, with little variability (Figures 3 and 4).

Figure 3: Trends in mean maximum air temperature in the River Offinso basin (Adapted from Amisah, *et al. 2009*)

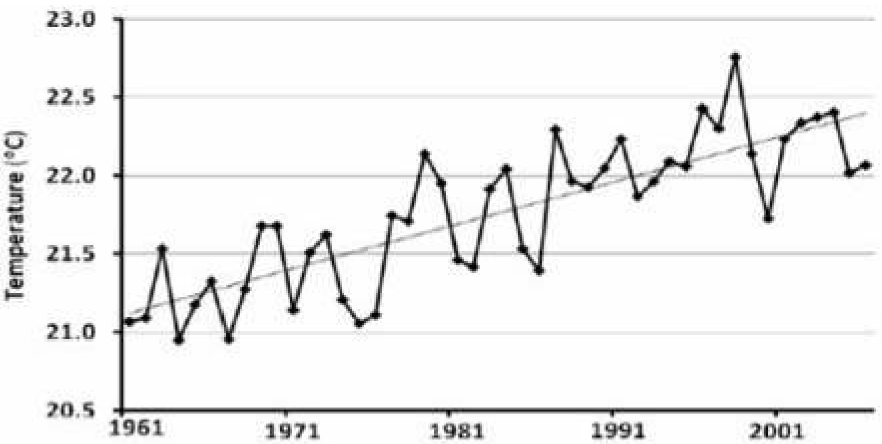

Figure 4: Trends in mean minimum air temperature in the River Offinso basin (From Amisah, et al. 2009)

5.1.2 Precipitation trends

The rainfall pattern in Ghana is consistent with the IPCC predictions for the West African sub-region (IPCC, 2007). Even though there is a general increase in temperatures, the rainfall pattern over the country has been unpredictable and erratic (EPA, 2000), with many parts of the country experiencing low amounts of rainfall (Nelson and Agbey, 2005). The situation in the Offinso District is not different; the district has recently been experiencing reduced annual rainfall affecting livelihoods and crop production. As reported by Amisah *et al.,* (2009), the area has seen a gradual, but consistent reduction in rainfall from 1961 to 2006 (Figure 5). Even though seasonal trends have not changed very much, mean annual precipitation decreased by 22.2%, from 1,448 mm in 1961-1970 to 1,127 mm in 2001-2006.

The erratic nature of rainfall patterns in the district is a major source of vulnerability to livelihoods (UNDP, 2007a).

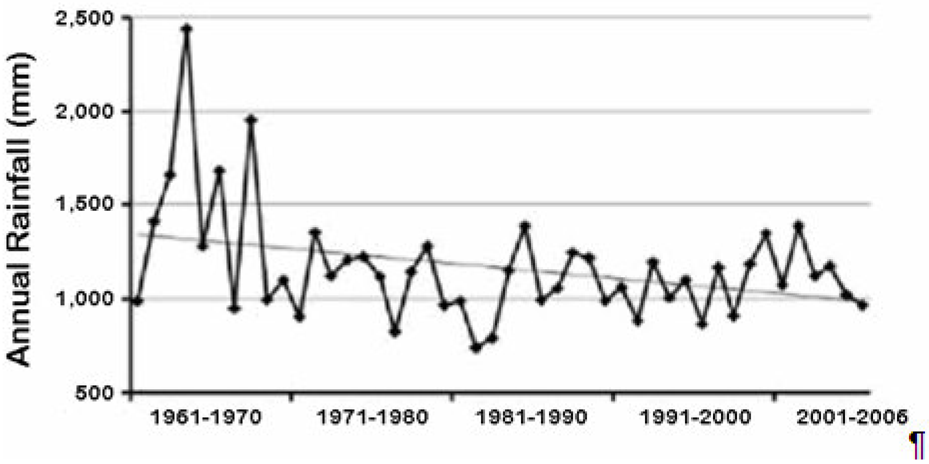

Figure 5: Trends in rainfall in the River Offinso basin during 1961 - 2006 (From Amisah, *et al.* 2009)

5.2 Lake Chilwa Catchment, Malawi

Malawi is located in eastern southern Africa, stretching across latitudes of 9-17°S. The country's topography is highly varied; the Great Rift Valley runs North to South through the country, containing Lake Malawi, and the landscape around the valley stretches at an elevation of around 800-1,200 m, but with peaks as high as 3,000 m. The country's climate is tropical, but the influence of its high elevation means that temperatures are relatively cool. In winter (June-July-August) temperatures drop to around 18-19°C and in the warmest months (September to January) temperatures range from 22-27°C (Table 2). Wet season rainfalls depend on the position of the Inter-tropical Convergence Zone (ITCZ) which can vary in its timing and intensity from year to year. In the south of Malawi, where Lake Chilwa Catchment is located, the wet season normally lasts from November to March with around 150-300 mm of rainfall per month, but rain continues into April in the north of the country as the ITCZ migrates northwards. Topographical influences also cause local variations in rainfall with the highest altitude regions receiving the highest rainfalls.

The inter-annual variability in the wet-season rainfall in Malawi is also strongly influenced by the Indian Ocean sea surface temperatures, which can vary from one year to another due to variations in patterns of atmospheric and oceanic circulation. The most well documented cause of this variability is the El Niño Southern Oscillation (ENSO). The influences of ENSO on the climate of Malawi are difficult to predict as it sits between two regions of opposing climatic response to El Niño. Eastern equatorial Africa tends to receive above average rainfall in El Niño conditions, whilst south-eastern Africa often experiences below average rainfall. The opposite response pattern occurs in La Niña episodes. The response of climate in each of these two regions and the extent of the area affected vary with each El Niño or La Niña event causing mixed responses in Malawi.

Table 2: Trends in temperature and rainfall including frequency of hot and cold days and nights, Malawi 1960-2006 (Adapted from McSweeney et al., 2008)

	Annual	**December-February**	**March-May**	**June-August**	**Sepember-November**
	Temperature				
Observed MEAN 1970-1999 (℃)	21.7	22.9	21.3	18.6	24.1
Observed TREND 1960-2006 (change in ℃ per decade)	0.21	0.24	0.20	0.23	0.14
	Rainfall				
Observed MEAN 1970-1999 (mm/month)	91.7	217.3	107.5	7.8	33.2
Observed TREND 1960-2006 (change in mm per decade)	-2.3 (-2.5%)	-5.8 (-2.6%)	-2.3 (-2.2%)	-0.2 (-2.8%)	-1.3 (-3.9%)
	Frequency of hot days				
Observed MEAN 1970-1999 (% frequency)	12.2	13.5	12.8	11.2	12.7
Observed TREND 1960-2006 (change in frequency per decade)	1.94	2.95	2.70	1.75	2.58
	Frequency of hot nights				
Observed MEAN 1970-1999 (% frequency)	12.0	13.1	12.0	11.6	12.3
Observed TREND 1960-2006 (change in frequency per decade)	2.59	4.09	2.98	1.43	3.07
	Frequency of cold days				
Observed MEAN 1970-1999 (% frequency)	9.1	9.4	8.8	9.3	9.2
Observed TREND 1960-2006 (change in frequency per decade)	-1.01	-0.8	-1.68	-1.22	-0.61
	Frequency of cold nights				
Observed MEAN 1970-1999 (% frequency)	8.2	7.7	8.0	7.9	8.5
Observed TREND 1960-2006 (change in frequency per decade)	-2.07	-2.38	-2.41	-2.25	-1.57

5.2.1 Temperature trends

The mean annual temperature in Malawi has increased by 0.9℃ between 1960 and 2006, an average rate of 0.21℃ per decade. This increase in temperature has been most rapid in summer (Dec-Jan-Feb) and slowest in Sept-Oct-Nov (Table 2). Daily temperature observations show significantly increasing trends in the frequency of hot days and nights in all seasons. The average number of 'hot' days per year in Malawi has increased by 30.5 (an additional 8.3% of days) between 1960 and 2003. The rate of increase is more obvious in Dec-Jan-Feb when the average number of hot days has increased by 3.9 days per month (an additional 12.7% of Dec-Jan-Feb days) over this period. The average number of 'hot' nights per year increased by 41 (an additional 11.1% of nights) between 1960 and 2003. The rate of increase is more obvious again in Dec-Jan-Feb when the average number of hot nights has increased by 5.5 days per month (an additional 17.6% of Dec-Jan-Feb nights) over this period.

The frequency of cold days and nights has decreased significantly since 1960 in all seasons except Sep-Oct-Nov (Table 2). The average number of 'cold' days per year has decreased by 16 (4.3% of days) between 1960 and 2003. This rate of decrease is most rapid in Mar-Apr-May when the average number of cold days has decreased by 2.4 days per month (7.2% of Mar-Apr-May days) over this period. The average number of 'cold' nights per year has decreased by 33 (8.9% of days). This rate of decrease is most rapid in Mar-Apr-May when the average number of cold nights has decreased by 3.2 nights per month (10.4% of Mar-Apr-May nights) over this period.

Observations of surface air temperatures from a weather station in the Lake Chilwa Catchment (Chancellor College weather station) showed a similar trend as the national temperature data. The data showed an overall increase in both minimum and maximum temperatures between 1982 and 2009 (Figures 6 and 7). Despite the overall increase in surface air temperature between these years, however, variations were observed across the years with lowest mean maximum temperature of 25.9 ℃ observed in 1996 and highest maximum temperature of 28℃ in 2008 (Figure 6). The lowest mean minimum temperature of 15.9℃ was observed in both 1982 and 1986 and the highest mean minimum temperature of 17.2℃ was observed in both years of 2005 and 2006.

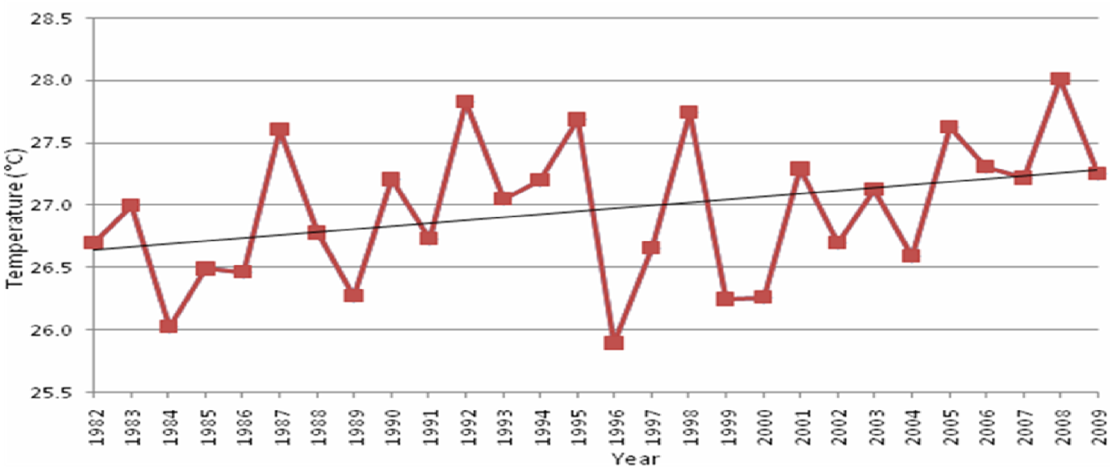

Figure 6: Trends in mean maximum air temperature in Lake Chilwa Catchment during 1982-2009

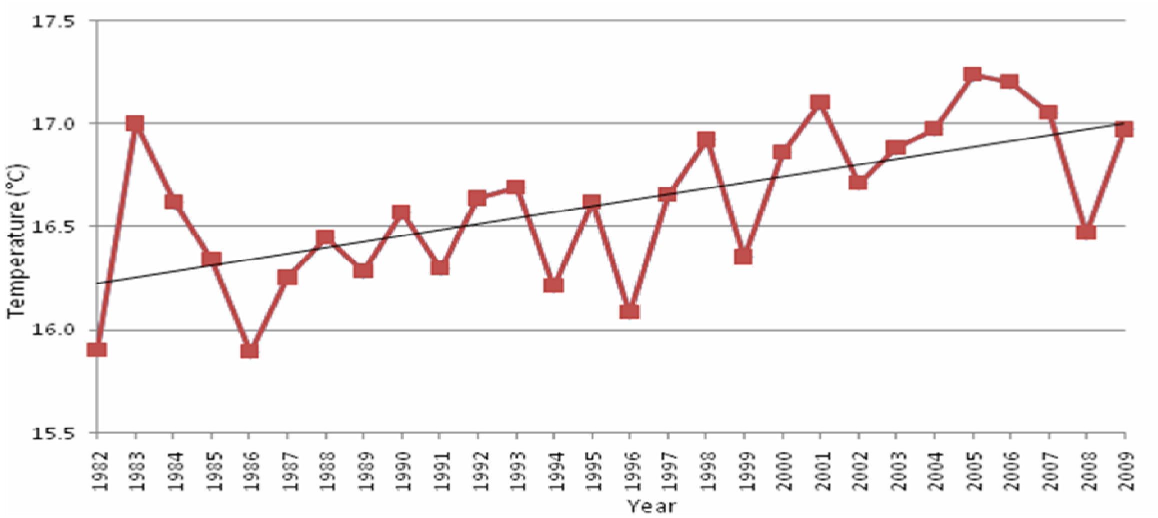

Figure 7: Trends in mean minimum air temperature in Lake Chilwa Catchment during 1982-2009

5.2.2 Precipitation trends

Year-to-year variability in rainfall is very strong in Malawi and this can make it difficult to identify long-term trends. Observations of rainfall over Malawi do not show statistically significant trends. Wet-season (Dec-Jan-Feb) rainfall over Malawi in 2006 was particularly low, causing an apparent decreasing trend in Dec-Jan-Feb rainfall but there is no evidence of consistent decreases. There are no statistically significant trends in the extreme indices calculated using daily precipitation observations (McSweeney *et al*., 2008).

The rainfall data at the weather station in the catchment (Chancellor college) showed variations in the amount of rainfall received each year in the Lake Chilwa Catchment with the highest mean annual rainfall of 2,021mm received in 1985 and the lowest mean annual rainfall of 442mm received in 1995 (Figure 8). The catchment experienced one of the worst droughts in 1995, in which the Lake Chilwa dried out completely. In contrast, during years of heavy rainfall, flooding was not uncommon in the catchment (e.g. the Phalombe Disaster of 1991).

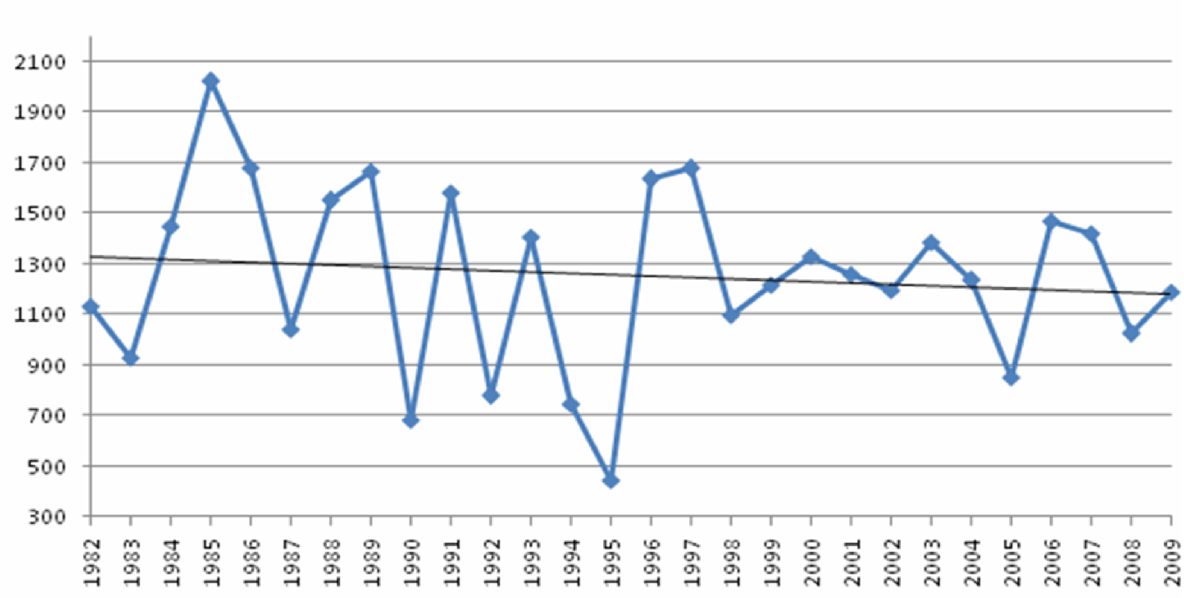

Figure 8: Trends in mean annual rainfall in Lake Chilwa Catchment during 1982-2009

These observations showed that the rainfall in the climate is both erratic and unpredictable. The catchment experienced both extreme droughts and floods, and their impacts on both aquatic and terrestrial ecosystems and the people in the catchment were severe. These impacts exacerbate the already fragile and devastated livelihoods of the majority of the households in the catchment.

5.3 Synthesis of local climate trends

There is every indication that anthropogenic climate change is likely to continue for many centuries (Karl and Trenberth, 2003). Even though there is no specific data on future climatic patterns for the Offinso District, projections are available for the various ecological zones in Ghana and can be used for the purposes of this report. It has already been established that the rainfall pattern in the Offinso District is variable, but has consistently reduced over time (Amisah *et al.,* 2009). Model projections for the semi-deciduous forest zone where the district is located portend a decline in rainfall in the future if the current business-as-usual attitude persists (EPA, 2000; 2008).

Climate change scenarios based on General Circulation Models (GCM) and Simple Climate Models (SCM) indicate that projected mean annual rainfall values in the semi-deciduous zone of Ghana will decline by -2.8%, -10.9%, and -18.6% in the year 2020, 2050, and 2080 respectively (EPA, 2008). Projections for rainfall patterns in the semi-deciduous forest zone by 2100 also suggest a reduction by 74 mm (EPA, 2008). As precipitation decreases, it is expected that temperatures for all the ecological zones in the country will continue to increase (Agymang-Bonsu, 2009).

Temperature for the semi-deciduous zone, on the other hand, is projected to rise by 0.8℃, 2.5℃, and 5.4ºC in the year 2020, 2050, and 2080 respectively (EPA, 2008). This shows that the temperature for the zone will continue to increase with time under business-as-usual scenarios.

In the case of Malawi, the current climate change and variability and the associated anthropogenic activities are making the biological ecosystems (including forests) and the well-being of the people more vulnerable to the impacts of future climate change. The projected future climate change will exacerbate the already existing critical situation, resulting in far reaching devastating consequences on the forest ecosystems and the livelihoods of the people that depend on them.

Based on the Global Circulation Models (GCM), the mean annual temperature in Malawi is projected to increase by 1.1℃ to 3.0℃ by 2060, and 1.5℃ to 5.0℃ by 2090. Under a single emissions scenario, the projected changes from different models span a range of up to 2.1℃. All projections indicate substantial increases in the frequency of days and nights that are considered ‘hot’ in the current climate. Annually, projections indicate that ‘hot’ days will occur on 14-32% of days by 2060, and 15-53% of days by 2090. Nights that are considered ‘hot’ for the annual climate of 1970-99 are projected to increase more quickly than hot days, occurring on 27-53% of nights by 2060 and 31-72% of nights by 2090. Nights that are considered hot for each season by 1970-99 standards are projected to increase particularly rapidly in Dec-Jan-Feb, occurring on 47-99% of nights in every season by 2090.

All projections indicate decreases in the frequency of days and nights that are considered ‘cold’ in the current climate. These events are expected to become exceedingly rare, and do not occur at all under the highest emissions scenario (A2) by 2090.

Projections of mean rainfall do not indicate substantial changes in annual rainfall. The range of projections from different models is large and straddles both negative and positive changes (-13% to +32%). Seasonally, the projections tend towards decreases in dry season rainfall (Jun-Jul-Aug and Sep-Oct-Nov), and increases in wet season rainfall (Dec-Jan-Feb and Mar-Apr-Mai). Projected changes in Jun-Jul-Aug rainfall range from -77% to +48% with ensemble median changes of -5% to -18% and in Sep-Oct-Nov, -63% to +40% with ensemble median values -7% to - 20%. Projected changes in Dec-Jan-Feb rainfall range from -8% to +25% with ensemble median changes of 4% to +11% and in Mar-Apr-Mai, -17% to +99% with ensemble median values of +1% to +7%).

Overall, the models consistently project increases in the proportion of rainfall that falls in heavy events in the annual average under the higher emissions scenarios (A2 and A1B), of up to 19% by 2090. These increases mainly arise from increases in heavy events in the wet seasons, Dec-Jan-Feb and Mar-Apr-Mai, and are partially offset by decreases in Jun-Jul-Aug and Sep-Oct-Nov. The models consistently project increases in 1- and 5-day rainfall maxima by the 2090s under the higher emissions scenarios, of up to 26 mm in 1-day events, and 39 mm in 5-day events. These also generally increase in Dec-Jan-Feb and Mar-Apr-Mai, but decrease in Jun-Jul-Aug and Sep-Oct-Nov.

From the evidence presented here one can conclude that there are observable changes in local climate in both pilot cases. These changes in local climate in combination with present land-use practices have negative implications on the ecosystem functioning and productivity. The most pressing issues related to resource degradation have been identified and are described in Chapter 6; they are the foundation for designing concrete adaptation measures as outlined in Chapter 7 and 8.

6. Resources Degradation and Vulnerability of Local Communities

6.1 Offinso District, Ghana

Climate change can lead to changes in physical, biological and socio-economic systems (IPCC, 2007; Rosenzweig *et al.,* 2008). Although no historical data on biomass in the Offinso District are available, a recent study on land cover types provides information on the current distribution of aboveground biomass and carbon stocks (Table 3).

Land cover type	Total Area in the district (ha)	Aboveground biomass (Mg/ha)[1]	Total C stock (Gg)[2]
Annuals (cultivated land)	18,721	177	1,661
Grass	1,091	79	43
Forest	6,712	382	1,281
Teak monoculture	2,327	177	206

Table 3: Distribution of estimated aboveground biomass (AGB) and C stock in land types in Offinso district (Source: Hapsari, 2010)

Forests in the district show the highest aboveground biomass per ha followed by agriculture land (i.e. maize, cassava, cocoyam with scattered local trees) and teak plantations. Because of its extent in area, agriculture crop land contains the highest amount of carbon stocks in the district.

The pressure on natural resources in the district can in part also be attributed to the fact that more than 90% of all households use firewood or charcoal a main source of fuel for cooking Figure 9). Although the surveys in 2003 and 2007 revealed a slight shift from firewood to charcoal, the need for biomass as fuel remains high and will further increase with increasing population.

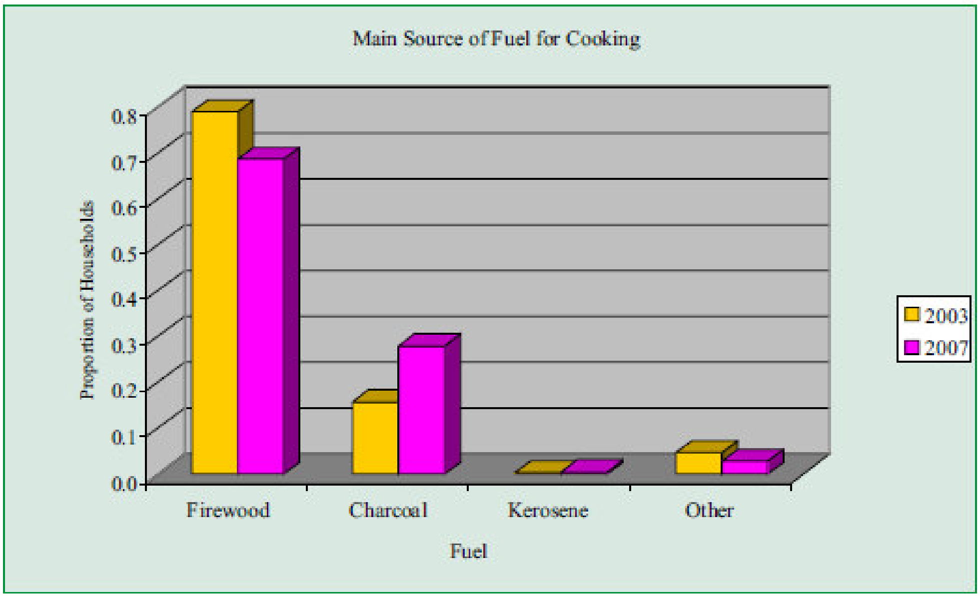

Figure 9: Main fuels used in cooking at Offinso District (Source: UNDP, 2007b)

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[1] Megagram: 10^6 g (= metric ton)

[2] Gigagram: 10^9 g

With increasing degradation of a previously forested landscape, the ecosystem is fast becoming a forest-savannah eco-tone and the vegetation is becoming predominantly savannah grassland. It is noteworthy that the situation has brought about an increase in the population of Fulani herdsmen migrating from the northern parts (northern Ghana and neighbouring Burkina Faso) to graze cattle. This has resulted in the increasing incidence of wild fires, and damage to farm crops by cattle as they browse food crops such as maize, or trample other crops to bring unprecedented hardship to already impoverished farmers whose yields have diminished as a consequence of the impacts of climate change on agricultural production.

Forest ecosystems in the West African region are experiencing impacts of climate change (IPCC, 2007) with large losses in biodiversity of foremost tropical forests (Idinoba *et al.,* 2009, Malhi *et al.,* 2008). Even though forest ecosystems in Ghana provide numerous non-timber forest products (Kotey *et al.,* 1998), climate change can affect the supply of these goods from the forests (Easterling and Apps, 2005; Idinoba *et al.,* 2009). The resulting impacts of resource degradation make local communities particularly vulnerable, affecting their livelihoods in many ways. In this section, the key impacts from resource degradation, as identified in consultation with the communities in the Offinso District, are discussed.

6.1.1. Forest loss due to wild fire

As indicated earlier, the Offinso District represents one of the most fire-prone areas in Ghana's forest zone, characterized by frequent annual bushfires. Although data on forest fires in the district are scanty, the degraded nature of the forests bear sufficient evidence of past and continuing incidences of wildfires that have brought about the gradual shift of the original high forest vegetation to savannah grassland in many places, as well as colonisation of large portions of the vegetation by invasive alien species such as *Broussonetia papyrifera* (Bosu and Apetorgbor, 2007) and *Chromolaena odorata*. This situation has resulted in declining soil fertility, biodiversity losses and associated impacts that adversely affect the livelihoods of local communities. It is known that reductions/variability in precipitation and temperature that are associated with climate change also affect the intensity and frequency of wildfires.

6.1.2. Decline in the availability of non-timber forest products

There is every indication that the availability of non-timber products is gradually declining in the Offinso District. A recent study by the Ecosystem Services and Climate Change Division of the Forestry Research Institute of Ghana in some forest fringe communities in the Offinso District showed that the availability of most non-timber forest products such as mushrooms, medicinal plants and snails have recently declined (Bosu *et al.,* 2010, unpublished report). Community dwellers have to travel long distances into the forest to collect some of these products. The decline in the availability of non-timber forest products, resulting from biodiversity loss related to the effects of climate change and variability is impacting negatively on the livelihoods of local communities in the district (Amisah *et al.,* 2009).

6.1.3. Reduction in agricultural crop yields

As noted by Hulme and New (1997) precipitation may be the most important key driver of many natural ecosystem processes. Communities in Ghana tend to be more vulnerable to climate change impacts because of widespread poverty, reliance on primary production, and overdependence on rain-fed agriculture (Nelson and Agbey, 2005). Local communities in the Offinso District, for instance, are heavily dependent on rain-fed agriculture and forest-based products (UNDP, 2007; Appiah *et al.,* 2009), which are very sensitive to climate change and variability (Fischer *et al.,* 2005; Bernier and Schoene, 2009). Therefore the current variability in rainfall patterns in the district has a significant adverse impact on community livelihoods (UNDP, 2007, Bosu *et al.,* 2010, unpublished data). In particular, considerable changes in rainfall frequency and its erratic nature have impacted negatively on communities that are predominantly cocoa and subsistence crop farmers (Amisah *et al.,* 2009; Gyampoh *et al.,* 2009). Also, prolonged rainfall shortages and droughts have brought about crop failures and income losses (Gyampoh *et al.,* 2007), thus affecting the livelihood of those communities.

Based on data from the 2000 headcount index and the 2003 Human Poverty Index, the incidence of poverty in the district was estimated to be 44.9% in 2007 (UNDP, 2007). The incidence was higher for rural population (48.2%), relative to the urban population (39.6%). Future climatic changes have the potential of worsening this situation by impacting negatively on food security, livelihoods and income levels of communities in the district. The situation is exacerbated by the fact that irrigation in the district is very low, thereby exposing farmers to the vagaries of the weather (Nelson and Agbey, 2005; UNDP, 2007).

Figure 10: Drying of cocoa beans in the Offinso District (G.A. Kwapong)

Apart from food crops, cocoa production (Figure 10) is one of the main economic activities in the Offinso District (UNDP, 2007). Cocoa is very sensitive to changes in climate, particularly rainfall and temperature (Ojo and Sadiq, 2010), and the pattern of cropping is related to rainfall distribution (Anim-Kwapong and Frimpong, 2005). The black pod disease which is very destructive to cocoa (Ayenor *et al.,* 2004) is also closely associated with weather and climate (Opoku *et al.,* 1999). Projected changes in temperature and rainfall in the semi-deciduous forest zone (EPA, 2000; 2008) could worsen soil moisture conditions during dry seasons and increase the vulnerability of cocoa production in the district (Anim-Kwapong and Frimpong, 2005). Changes in climate may also alter stages and developments of pathogens, modify host resistance, and could also change the physiology of host-pathogen interaction (Anim-Kwapong and Frimpong, 2005). Thus, unmitigated changes in the climate and its variability could worsen the declining cocoa crop yields with further adverse impacts on farm income and livelihoods (Anim-Kwapong and Frimpong, 2005; Ojo and Sadiq, 2010).

6.1.4. Declining potable water supply and associated risk of water-borne diseases

It has been observed that decreasing mean precipitation in the district has affected the flow of rivers and streams (Gyampoh *et al.,* 2008). Other studies in Ghana have concluded that runoffs or discharges in all the major river basins in the country are sensitive to changes in precipitation and temperature (Agyemang-Bonsu, 2006). The gradual rise in temperature and reduction in annual precipitation has led to water scarcity in many communities in the district (UNDP, 2007; Gyampoh *et al*., 2008). Although the high rates of deforestation and forest degradation is a contributory factor (UNDP, 2007), the changes in climatic patterns have exacerbated the problem (Amisah *et al.,* 2009; Eastaugh, 2010). Research has found that discharges in all the major water bodies in the district have been low, and some rivers and streams completely dried up (Gyampoh *et al*., 2009). Flow into River Offin, a major river in the district, has decreased from 6.9 m^3 per second in 1957 to 3.8 m^3 per second in 2006 - representing a reduction of 45% (Gyampoh *et al*., 2007).

In the dry season of 2006, the flow was so low that the river bed was exposed (Gyampoh *et al.,* 2009; Figure 11).

Figure 11: The flow into the Offin River basin from the tributary rivers and streams declined significantly during the dry season in 2006; eventually the main river dried up (B.A. Gyampoh)

This situation is a result of gradual drying up of tributary rivers and streams in the River Offin basin. The Anyinam River which is the main source of water for the Anyinam community dried up in 2009. The situation is more worrying since some large urban and peri-urban communities such as Akomadan and Namong obtain their drinking water from some of these rivers and streams (UNDP, 2007). The Abofour community, for instance, has been experiencing severe water shortages during the dry seasons (UNDP, 2007). In most cases, the rivers and streams in the district are the main or only source of water for some communities. Hand-dug wells which provide an alternative source of water for most communities are also drying up in the dry seasons, indicating a possible reduction in ground water (Gyampoh *et al.,* 2009).

Climate change and land use changes are having serious impacts on health in West Africa, Ghana being no exception, and can undermine the potential for achieving the Millennium Development Goals (Thomson *et al*., 2004; UNDP, 2007; Gyampoh *et al.,* 2009). In the Offinso District this impact is reflected in the observed increase in the incidence of diseases. Studies show that there has been an increase in the incidence of both infectious and parasitic diseases in the Offinso District (UNDP, 2007; Gyampoh *et al.,* 2009; Offinso Municipal Assembly, 2009), which are easily influenced by climate change and variability (Patz *et al.,* 2003; Thomson *et al.,* 2004; Gyampoh *et al.,* 2009).

Mosquito-borne diseases are among the diseases most sensitive to climate (Patz *et al.,* 1996). Climate, particularly increased temperature, has been found to influence malaria risk (Hunter, 2003); climatic changes and variability have the potential to shift the malaria vector's geographic range, increase reproductive and biting rates, and shorten the incubation period (Patz *et al.,* 1996; Hunter, 2003). Gyampoh *et al.,* (2009) have reported that there has been an increase in the incidence of malaria as people are increasingly exposed to mosquito bites. People tend to sleep in the open on hot nights, or leave windows open at night. This predisposes them to mosquito bites. Low rainfall also leads to an increase in the number of breeding sites by slowing river/stream flow or causing rivers/streams to dry into pools that breed mosquitoes.

An earlier study in the district by the UNDP (2007) also found that the most frequently reported ill-health was malaria (Tables 4 and 5). Records from the District Health Directorate show that more than half of the out-patient cases in the district health facilities involve malaria. The absolute number of reported cases keeps increasing. Indeed, malaria-related deaths in the district rose from 14 in 2002 to 28 in 2005 (UNDP, 2007).

	2001		2004		2005	
	Number	Percent	Number	Percent	Number	Percent
Malaria	22526	35.13	28838	57.57	29335	54.90
Upper Respiratory Tract Infection	5744	8.38	2513	5.01	2794	4.81
Diarrhoea	3025	4.41	2787	5.56	2730	4.70
Rheumatism	1759	2.57			1133	1.95
Acute Eye Infection			1481	2.95	1279	2.20
Home Accidents					1628	2.80

Table 4: Major causes of morbidity in the Offinso District (Adapted from UNDP, 2007a)

Causes of Death	2002	2003	2004	2005
Malaria	14	24	19	28
Anaemia	16	30	10	16
Diarrhoea	15	22		
HIV/AIDS		15	11	15
Hypertension	12	12	12	
Septicimea		23		
Typhoid Fever		38		

Table 5: Mortality in the Offinso District (Adapted from UNDP, 2007a)

Another vector-borne disease which is affecting some communities, particularly Asuboye community, is river blindness. Adult blackflies (*Simulium* spp.) have been the cause of river blindness in the world, especially in West Africa (Thomson *et al.,* 2004; Yaméogo *et al.,* 2004). These flies are also influenced by environmental determinants such as wind, rainfall, and river discharges (Hunter, 2003; Thomson *et al.,* 2004). Studies have indicated that rainfall shortages can potentially influence the distribution of *Simulium* spp. (Walsh *et al.*, 1993).

Even though river blindness (onchocerciasis) has been eliminated in West Africa and in most parts of Ghana (Yaméogo *et al.,* 2004), blackfly invasion is still prevalent in the Asuboye community (Offinso Municipal Assembly, 2009). Patz *et al.,* (2003) noted that the most influential factors for vector-borne diseases include temperature and precipitation, and to a lesser extent, wind and the duration of daylight.

The low rainfall pattern which leads to slow river/stream flows potentially increases the breeding sites of blackfly (Hunter, 2003; Thomson *et al.,* 2004).

Apart from these, other heat and water related diseases are becoming more common in the district (Gyampoh *et al.,* 2009). During the prolonged rainfall shortages, water sources become scarce (Gyampoh *et al.,* 2008), stagnated and contaminated thereby increasing the incidence of diarrhoea and bilhazia (Gyampoh *et al*., 2009). Water shortage has also dire consequences on personal hygiene leading to infectious skin diseases. For instance, shingles and other skin diseases, some of which were formerly rare, have become common during periods of high temperatures (Gyampoh *et al.,* 2009).

It is therefore clear that future climatic changes may have dire consequences on the livelihood of the people in the district. Most communities in the Offinso District are rural and depend very much on products from the forest ecosystem (Appiah *et al.,* 2009; Hapsari, 2010). Unbridled climate change and variability are thus likely to alter the productivity in these forest ecosystems (Maroschek *et al.,* 2009). Further changes in temperature, coupled with extremes of weather conditions may affect the survival, availability and distribution of timber and non-timber species in the forest, worsen the incidence and frequency of wildfires, and result in further decline in agricultural yields and potable water supply, with increasing associated risks in community health. All of these will worsen the poverty situation in the district if concrete and appropriate adaptation strategies are not instituted.

6.2 Lake Chilwa Catchment, Malawi

Forests, woodlots and trees in Malawi are adversely impacted by anthropogenic disturbances, mainly because of the combined effects of socio-economic dependence of the households and the national economy on forests, agriculture and other natural resources (NAPA, 2005). These disturbances coupled with changes in climate have resulted in the following observed impacts on the landscape ecosystem and livelihoods of the local communities.

6.2.1 Poor productivity of planted trees on farm

The Malawi government initiated a series of tree planting programmes e.g. the National Tree Planting Programme (NTPP), the Rural Fuelwood and Poles Research Project, the Wood Energy Project, in order to facilitate and encourage individual farmers, local institutions, schools and churches/mosques to participate in tree planting and tender for the already planted trees for their domestic use and protecting the environment. It was estimated that over 300 million trees had been planted throughout the country during 2008 (Forestry Department). However, walking around the landscape across the country, including the Lake Chilwa catchment, there are not many of these trees standing. An evaluation study conducted in the Lake Chilwa catchment (Ngulube *et al.*, 1999) reported that most of the trees planted through these programmes at the household level are poorly tendered for, resulting into death or low growth rate. Domestic animals e.g. goats also browse and destroy some of the planted tree species. The result is a landscape devoid of trees or of poor growth standing trees, which only insufficiently meet the tree and wood needs of the societies in the catchment. Figure 12 shows individual trees in the Lake Chilwa landscape.

Figure 12: Part of the landscape of Lake Chilwa Catchment (H. Utila, 2010)

6.2.2 Loss of indigenous trees on communal areas, riverbanks and surrounding forest reserves

A number of socio-economic studies about the preferences and the use of tree species which was carried out in the catchment and surrounding communities showed that the use of species was highly selective for particular purposes provided that the preferred species were still available (Coote *et al*. 1993; Lowore *et al*., 1995). For instance, Lowore *et al*., (1995) found out that the most preferred firewood species in most communities surrounding the catchment were all indigenous tree species, in particular *Julbernardia paniculata*, followed by *Brachystegia boehmii* and *B. spiciformis.* These species were given preference over others because of their hot flame, burning with little smoke and having long-lasting embers. However, the species were no longer readily available in most areas and households tended to use any available tree species including crop residues as energy source. BEST Malawi (2009) reported that 6.7% of the total biomass energy consumption in Malawi was from crop residues in 2008. The same observation regarding the scarcity of preferred tree species was made for charcoal and curio production, construction poles and timber (Coote *et al*., 1993). Apart from the resulting impacts on the livelihoods of the local communities, the biodiversity of the catchment was reduced due to overutilization of the preferred species. This may have far-reaching consequences on the stability of the existing species in the catchment.

The non-timber forest products from the catchment included medicinal plants, edible mushrooms and wild fruits which are not only consumed but widely traded by both the rural and urban communities of Zomba City (Figure 12). The catchment has a number of edible mushroom species. *Termitomyces titanicus,* the world's largest and tastiest mushroom also occurs in the surrounding Liwonde Forest reserve (Piearce, 1987). These edible mushroom species exist symbiotically with most of the miombo woodland species. However, due to the reduction in stocking levels of these symbiotic tree species in the catchment, the productivity of these edible mushrooms has also declined.

Figure 13: Villagers selling wild mushrooms on Zomba-Liwonde road. (G. Meke)

Fruit species include *Uapaca* spp., *Strychnos* spp., *Parinari curatellifolia* and *Anisophyllea boehmii* which used to be an important dietary component of the rural dwellers in the catchment. They are also sold to meet specific cash requirements in case of crop failure (Akinnifesi et al. 2008). The stocking levels of these species have tremendously declined in the recent past as a result of cutting them down for either firewood or charcoal production to sustain household income and energy needs.

Several tree species are used in treating various ailments (Figure 14). Interviews with traditional healers (Barany *et al*., 2005) in Malawi revealed that medicinal plants are used in the treatment of at least 10 illnesses and symptoms related to HIV/AIDS. Medicinal plants in general are becoming less available with 93% of herbalists reporting a general decrease over the last ten years. Thirty-two medicinal plant species were identified as vulnerable to overexploited and increasingly difficult to source in the last 5 years, including species used in the treatment of HIV/AIDS-related illnesses. When asked about the major factors driving this change, 85% of respondents mentioned destructive harvesting methods as the main threat, followed by increasing demand for trade (77%), commercial harvesting by outsiders (69%), conversion of forest land (54%), policies that prohibit collection (23%), and finally competing uses (15%).

Figure 14: Selling of traditional medicine at Jali market, Zomba (G. Meke)

6.2.3 Decline in productivity of agricultural crops

According to the Lake Chilwa Wetland State of the Environment Report (2000), 90% of all households in the catchment are short of food by the end of February every year. This figure is a telling indicator of the poverty and vulnerability of the people in the catchment.

Degradation in the upper catchment, including deforestation and forest degradation, poor agricultural practices and lack of soil erosion control measures and steep slope cultivation have negatively affected the productivity of agricultural crops in the catchment. The declining fertility of soils and undesirable cropping patterns are not only a threat to household food security, but also to the environment and the natural resources of the catchment.

Nutrient budgets for the catchment show a net annual depletion of nitrogen (N), phosphorus (P), and potassium (K) as a result of long-term cropping with little or no external nutrient inputs (Mughogho, 1998). This is a long-standing phenomenon related to nutrient exhaustion from cropland. In the past, soil fertility was restored by many years of fallow through a practice known as shifting cultivation (Kikafunda, 1997, as cited by Madzonga, 1999). This practice ensured that nutrients recycled in plant biomass over a decade or more could be used for crop production for a couple of years before the land was left to regeneration for another decade. This was possible because land was plentiful and it was possible to leave a piece of land to regenerate for a decade or more, while in the interim, cultivating another piece of land for continued food supply. The declining size of individual land holdings have resulted in continuous cropping of the land which has brought about nutrient depletion in the soil through crop removal and other soil degrading processes.

6.2.4 Declining fish catch from the lake

Lake Chilwa is a shallow lake, saline and not exceeding 6 m depth at peak water levels. Because of its shallowness, nutrient recycling is efficient, making Lake Chilwa one of the most productive lakes in Africa (Chiotha, 1996). In some years, the annual catch can approach up to 25,000 tons, but the average is around 13,000 tons. In 1979 fish production from Lake Chilwa contributed approximately 43%, while in 1990 its contribution was 33% to the total annual catches in Malawi. Despite the decline, the lake has an important bearing on the nutritional requirement of Malawi’s population. Supply of fish to the local population and the fishing-related activities can, therefore, be some of the appropriate means through which food security and poverty eradication policy objectives of the Government of Malawi can be achieved.

The lake has dried up several times since 1879 (Lancaster, 1979). Records show that reduced catches and fish mortalities occurred during the minor and moderately severe recessions of 1900, 1914-15, 1922, 1931-32, 1934, 1954, 1960-61, 1967, 1973 and 1995, (Njaya 1998). Following a severe recession, the fishery usually takes 3 to 4 years to fully recover, but considering its enhanced fertility due to drying and oxidation of the organic matter, catches can be doubled after recovery (Kabwazi and Wilson, 1996).

6.2.5 Declining potable water supply and associated risk of water-borne diseases

The Lake Chilwa Catchment boasts a network of river systems such as Domasi, Songani, Phalombe, Naisi, Likangala, Thondwe, and Namadzi, which drain water into the lake. The existence of the lake and a network of rivers together with the low-lying nature of the land resulted in the creation of a long wetland whose significance has largely to do with the cultivation of rice through both formal and informal irrigation. The low-lying topography makes the basin vulnerable to water logging and flooding especially during the rainy season. Since most of the rivers spring from Zomba Mountain and snake through the urban areas of the Zomba City, the waters from the rivers are heavily competed for domestic and productive purposes. The rivers are also polluted with sewage wastes and other rubbish which are deposited into the river, particularly as they pass through the urban settlements. Consequently, the inhabitants of the basin largely depend on man-made water sources like boreholes, water taps, hand dug protected and unprotected shallow wells, etc. for potable water uses.

Not all these sources provide water throughout the year: most of them dry up during the dry months of the year. In addition to poor standards in the construction of the sources, the high temperatures of the basin invariably exacerbate the drying up of water sources (Lake Chilwa

State of Environment, 2000). A water point assessment conducted in the catchment (Forestry and Horticulture Department of Bunda College, 2006) revealed that 34% of the total (3858) water points (boleholes, water taps and protected shallow wells) available in the catchment were non functional. The non-functionality was mainly caused by drying up of the aquifer due to lowering of the water table. It is expected that this situation worsens with the projected increase in temperature due to climate change. The study conducted by Masamba and Mulwafu (2008) on the water quality in the catchment showed that water resources were of an acceptable chemical quality but they were not safe for direct human consumption due to high faecal coliforms and faecal streptococci. Local communities therefore run the risk of suffering from waterborne diseases, such as diarrhoea and dysentery, if they consume untreated water.

6.3 The Climate Change Adaptation Matrix

In this section a summary Table for each pilot case is presented which links priority issues related to resource degradation and associated vulnerabilities described above with appropriate adaptation measures outlined in the Chapters 7 and 8. The two Tables are intended to highlight the fact that designing meaningful adaptation projects on the ground is about setting priorities involving the selection of a few but most effective adaptation measures.

Resource degradation	Vulnerabilities	Adaptation measures
Loss of forests due to wildfire	Loss of biodiversity; Shift of forest vegetation to grassland/savannah; Loss of agricultural lands.	Community-based fire prevention and control; Restoration of degraded forest areas. (Chapter 7.1)
Decline in the availability of non-timber forest products	NTFP collectors travel longer distances; Many useful NTFPs now in short supply;	Training in sustainable NTFP-management. Domestication of medicinal plants Promotion of alternative livelihood schemes (Chapter 7.2)
Reduction in agricultural crop yields	Lower incomes from food crop production; Lower incomes from cash crop production Increasing Human Poverty Index in the district.	Increase of crop diversification, Soil conservation practices through agroforestry; Improvement of agricultural extension services (Chapter 7.3)
Declining potable water supply and associated risk of water-borne diseases	Drying up of streams, and scarcity of drinking water in rural, urban and peri-urban areas during the dry season; Upsurge in incidence of malaria, onchocerciasis	Improve availability and access to water sources; Watershed management; Improve public health (Chapter7..4)

Table 6: Major impacts of climate change on forests and people in the Offinso District in Ghana with the associated vulnerabilities and appropriate adaptation measures

Resource degradation	Vulnerabilities	Adaptation measures
Poor productivity of planted trees on farm	Insufficient construction poles and firewood to sustain the livelihoods of local communities on the catchment.	Training on tree management Promotion of drought-tolerant multi-purpose tree species (Chapter 8.1)
Loss of indigenous trees on communal areas, riverbanks and surrounding forest reserves	Preferred indigenous tree species for household purposes in the catchment area are rare or extinct	Conservation and rehabilitation of indigenous woodlands Establishment of community-based protection of indigenous woodlands (Chapter 8.2)
Decline in productivity of agricultural crops	Increased food insecurity and loss of household income	Increase crop diversification Improve soil and water conservation practices (Chapter 8.3)
Decline of fish catch from the lake	Increased food insecurity and loss of household income	Regulate fish catch from the lake Enhance aquaculture farming (Chapter 8.4)
Declining potable water supply and associated risk of water-borne diseases	Drying up of streams, and scarcity of drinking water during the dry season; Increased incidence of diarrhoea and other water borne diseases	Improve availability and access to water sources; Watershed management; Promote community-based water and sanitation programs (Chapter 8.5)

Table 7: Major impacts of climate change on forests and people in the Lake Chilwa Catchment, Malawi, with the associated vulnerabilities and appropriate adaptation measures

7. Adaptation Strategies and Specific Activities in the Offinso District, Ghana

Risks to future climatic changes and variability are evident in climate-sensitive sectors such as forestry (Adger *et al.,* 2003; IPCC, 2007), with serious consequences for fringe communities (Spittlehouse and Stewart, 2003; Locatelli *et al.,* 2010). The potential impacts of climate change on forests and forest-dependent communities (Idinoba *et al.,* 2009; Berneir and Schoene, 2009) require adaptation measures that would moderate the vulnerability to these future changes (Spittlehouse and Stewart, 2003; Millar *et al.,* 2007; Guariguata *et al*., 2008).

Initiatives to deal with climate change and variability in tropical countries, including Ghana, have mainly focused on mitigation (Canadell and Raupach, 2008; Guariguata *et al.,* 2008; Eastaugh *et al.,* 2010). However, according to Dixon *et al.,* (1996) adaptation to global climate change may be a more realistic strategic option for Ghana than intensive mitigation measures. Smit and Pilifosova (2001) defined adaptation to climate change as adjustments in ecological, social and economic systems to the effects of climate change. Adaptation options to climate change and variability are relevant for both impact assessments and policy planning and development (Smit *et al.,* 2000; Tachie-Obeng *et al.,* 2010).

Successful adaptation of forests and people to climate change requires a broad approach incorporating a wide range and a mix of measures at the community level. Such measures need to address issues related to:

- Landscape-level planning involving a multitude of stakeholders with variable values, interests and preferences;
- Tenure systems and access to natural resources that include a broad spectrum of ownership, access, use and management rights to forests which shape the relationships between people and forests by defining who can use what resources, for how long and under what conditions;
- Complex mix of livelihood activities at a farm level (e.g. food and energy security, income generation and off-farm job opportunities, health, education and family planning);
- Good governance at village-level including transparency and accountability in decision making, financing and political landscape; and
- Capacity building to enable community groups to participate adequately in decision making and forest management.

While the above-mentioned issues can be addressed by working with local communities and government agencies at district level, broader policy concerns such inter-sectoral policy coordination, interaction and coherence that reduce conflicts among policy goals between sectors (e.g. increase in the profitability of another sector such as tobacco (agriculture) and bio-fuel crop (energy) resulting in deforestation) would need to involve provincial and national governments, most probably in separate projects and programmes.

It is further emphasized that the adaptation measures outlined in the results of the two case studies should be understood as possible options or approaches that could be implemented in a specific community context. Various communities and their leaders react differently to new ideas and innovations including adaptation measures, even if these communities belong to the same pilot or project area. Therefore, it is advocated here that each proposed adaptation measure first needs to be subject to intensive deliberation among community members before such measures are accepted for implementation. Thus, case studies, such as these cannot replace the usually longer-term process of awareness creation, motivation and careful social transformation towards changing perceptions and land-management practices.

In this section, past and present measures on adaptation related to forests and resource degradation within the context of the most important impacts on people are discussed, and appropriate, concrete and specific adaptation measures that build on the existing local strategies are proposed to make them more effective and easier to implement.

7.1 Forest loss due to wildfire

Past and present adaptation measures

According to the IPCC (2007), communities have developed a range of practices and options which have helped them to adapt to climate change and its impacts. Communities in the Offinso district have already developed some coping strategies to deal with the current changes in climate and weather conditions (FORIG, 2003; Amissah *et al.,* 2010), based on accumulation and transmission of inter-generational local indigenous knowledge (Berkes *et al.,* 2000). Based on traditional knowledge acquired over the years, farmers and local people in the district have developed knowledge in wildfire management and are applying this to cope with the impacts of wildfire (FORIG, 2003; Amissah *et al.,* 2010).

Techniques such as burning in smaller portions and proper pressing of the vegetation to prevent spot fires have been practiced by farmers over the years. Moreover, farmers have developed the practice of burning vegetation against the direction of the wind at the site of burning (Amissah *et al.,* 2010). They check the direction by throwing sand into the air or watch the movement of leaves to ensure the suitable wind condition for burning (FORIG, 2003). Local people also use the leaf flush of *Moris mesozygia* (a forest tree), and the first two months after the dry season as clues to identify the time for safe burning (FORIG, 2003).

When there is fire outbreak, local people use whistling and shouting to transmit fire warning to others (FORIG, 2003). In addition to all these, fines are imposed on people who set fire to the forest (Gyampoh *et al.,* 2009). Although some of these practises may be unconventional and unsustainable, these locally developed practices could be combined with available scientific knowledge to enhance wildfire prevention and management.

Proposed adaptation measures/activities

As indicated above, the strategies adopted by communities in the Offinso District to combat the devastating impacts of forest fires on their well-being might be rudimentary and not based on science. However, the inter-generational local knowledge and the underlying logic have not been entirely ineffective. Even so, more concrete adaptation strategies such as more formal community-based fire prevention and control strategies will be more effective in enhancing their coping and adaptation capabilities in situations where the sheer magnitude and scale of the problem with time supersedes the capacity of communities to cope effectively. In addition to this, strategies for the restoration of degraded forest areas will be necessary in order to mitigate impacts such as losses in biological diversity consequent to shifts in the composition of the forest vegetation, as well as the loss of important agricultural lands and other benefits. These measures are as outlined in Table 8.

Table 8: Proposed adaptation activities/measures to mitigate the impacts of resource depletion resulting from forest fires on communities in the Offinso District

Key vulnerabilities	Specific adaptation strategies/activities
1. Loss of biodiversity; 2. Shift of forest vegetation to grassland/savannah; 3. Loss of agricultural lands.	1. **Community-based fire prevention and control**. Specific activities include: • Wildfire prevention and control measures at all levels involving local communities. Local people must be encouraged with incentives to report arsonists and fire occurrence. • Punitive measures such as high fines and/or long prison terms will be required to deter people from using fire indiscriminately. • There must be awareness creation among local people on wildfire ecology, prevention and control, e.g., wildfire behaviour, establishment of green fire breaks. Training must also be provided at all levels on the proper use of fire. • Improvement in monitoring by Community Fire Volunteer Groups especially during the period of land preparation by farmers, and improved incentives for Volunteer Groups. • Prescribed early burning, i.e., periodic early burning at the beginning of dry season. This fuel load management tool can facilitate fire suppression efforts by potentially reducing the intensity, size and damage by wildfires. 2. **Restoration of degraded forest areas**: The specific activities are: • The use of tree species mixtures as a technique for establishing new plantations of indigenous plantations. Suggested species are Terminalia superba, Triplochiton scleroxylon and Ceiba pentandra. (These may be grown in mixtures with proven fast-growing exotics such as Teak, Gmelina and Cedrela). This plantation type has the potential to achieve high product diversification, support biodiversity and rehabilitate degraded areas. It can also provide small landowners and farmers a form of insurance to protect them from future market uncertainties. • Emphasis on forest rehabilitation using indigenous tree species Indigenous tree species must be used in plantation establishment because they have the potential to out perform most exotic species. These can be used to provide a wide range of goods and services, and also increase product diversification. Plantations of indigenous species are capable of providing suitable structural and understorey conditions to support biodiversity. • Reduce/control invasive alien species such as Broussonetia. This can be done through manual removal of shrubs and by using cut-and –squirt procedure to reduce pole-sized trees. Also, the use of fast-growing indigenous species can minimize the threat of Broussonetia invasion.

7.2 Decline in the availability of non-timber forest products

Proposed adaptation measures/activities

Until quite recently, NTFPs have been abundant throughout the high forest zone of Ghana. Consequently, not much attention has been paid neither to their conservation nor to harvesting intervals. The misconception prevailed that there exists a vast, inexhaustible supply of these products from a seemingly perpetual forest resource. For this reason, no traditional strategies were adopted for their protection, except for the protection of sacred groves in several forest fringe communities as a conservation measure for several other purposes, mostly satisfying the spiritual values that were intricately linked to traditional/local values.

However, with gradually dwindling supplies of important NTFPs such as spices, medicinal plant parts (roots, leaves, exudates, bark, etc) the realisation of imminent depletion of such NTFPs is gradually dawning on communities, especially in the Offinso District. In this District, pressures other than increasing demand (e.g., extreme events such as forest fires, drought, floods, etc.) have taken a significant toll on the original high forest/vegetation to the extent that many NTFP species have become scarce or difficult to find, and collectors have to travel longer distances to find them.

In response to these impacts, communities are now dealing with the gradual decline in NTFPs' availability from the forest through commercial production. Local people have turned to bee-keeping, snail farming and rabittery in some communities in the District (Boateng, 2008). This helps them to improve their income by providing alternative sources of livelihood for them.

In tandem with theses recent traditional strategies for the conservation and sustainable use of NTFPs the following strategies are proposed (Table 9):

Table 9: Proposed adaptation activities/measures to mitigate the impacts of the decline in NTFPs' availability on communities in the Offinso District.

Key vulnerabilities	Specific adaptation strategies/activities
1. NTFP collectors travel longer distances; 2. Many useful NTFPs now in short supply;	1. **Training in the management and sustainable production of NTFPs**. Capacity building programmes such as workshops and pilot demonstration projects/activities will enhance community acceptance and participation in such schemes. 2. **Domestication of useful medicinal plants and other NTFPs in home-gardens and farms**. This activity is already practised on a limited scale and can be up-scaled through more efficient demonstration programmes in selected communities. 3. **Promotion of alternative livelihood schemes** (bee-keeping, soap-making, etc) by promoting the establishment of co-operative associations to improve access to credit facilities from Banks, etc.

7.3. Reduction in agricultural crop yields

Past and present adaptation measures

As an adaptation strategy, local communities in the Offinso District have been involved in the practice of agroforestry for quite some time (Boateng, 2008). In adjusting to insufficient income from farming, and scarcity of fertile land, farmers have developed adaptation strategies to optimize available lands. Some of the old practices include home gardens, and intercropping of cash crops such as cocoa and oil palm with food crops (Boateng, 2008). Typically, farmers raised an assemblage of plants which included trees, shrubs and crops growing in or near their homesteads. Another popular practice is the growing of cash crops, especially cocoa and oil palm together with crops such as maize, plantain and cassava (Boateng, 2008). The farmers depend on the food crops in the short term and the cash crops improve their income base in the long term. This practice is still very common in many parts of Ghana (Duguma *et al.,* 2001).

More recently, local people have adopted agroforestry practices or systems such as woodlot cultivation, taungya, alley cropping, and wind breaks to diversify their income base and provide other services (Boateng, 2008; Haspari, 2010). Farming communities in the district have also started planting drought tolerant crop species and varieties (e.g., cassava), and crops which hitherto were mostly confined to the Savannah zone (Gyampoh *et al.,* 2009; Bosu *et al.*, unpublished report). Farmers are also using the mixed-cropping system, and interchange crops, while others are now farming near river plains to maximise the possibility of increasing their harvest (Gyampoh *et al.,* 2009). Moreover, some farmers synchronize planting to coincide with the onset of the rains (Bosu *et al.,* unpublished report). Some farming communities also use irrigation systems (Gyampoh *et al.,* 2009), but this is not a frequent practice (UNDP, 2007).

Proposed adaptation measures/activities

Notwithstanding the present adaptation strategies adopted by the communities in the Offinso District to ameliorate the decline in crop yields, income from agricultural activities remains low owing to low yields. Accordingly, the following strategies are proposed for more effective impact (Table 10):

Table 10: Proposed adaptation activities/measures to enhance agricultural productivity in the Offinso District

<table>
<tr><th>Key vulnerabilities</th><th>Specific adaptation strategies/activities</th></tr>
<tr><td>1. Lower income from food crop production (yam, vegetables, maize, etc).
2. Lower income from cash crop production, (e.g., cocoa).
3. Increasing Human Poverty Index in the district.</td><td>1. Increase crop diversification, and use early maturing and/or drought-resistant varieties. Farmers should be encouraged to modify their farm management practices. Measures such as intercropping and crop rotation can help buffer nutrient cycle and reduce soil erosion. The use of drought resistant cultivars and varieties can help to reduce the risk of crop failures during periods of reduced rainfall. The timing of farming practices such as planting, weeding, and harvesting must be adjusted in relation to the weather pattern. Also, hardy species of livestock should be used in animal production to increase resilience to extreme weather conditions. Although not new, demonstration activities will facilitate uptake of such strategies, in particular when they produce better results.
2. Improve soil conservation practices through agroforestry:
• Farmers must be encouraged to incorporate trees in their crop systems to help reduce soil erosion, and improve water infiltration.
• Improvement of irrigation systems. Access to water by farmers is likely to increase their resilience to dry conditions. The District Assemblies, together with the district office of the Ghana Irrigation Development Authority must therefore collaborate in order to increase investments in the construction of small dams. This will ensure that water is available to farmers throughout the year.
3. Improve agricultural extension services, etc.
• Since most farmers, who are exposed to new technologies, are not sufficiently educated, the Regional and District Agricultural Extension Services and Protection and Regulatory Services must expand their extension activities in the communities.
• There should be more education, and awareness creation about the use of weedicides, and other practices to help protect beneficial soil organisms and improve the health of farmers and their families.</td></tr>
</table>

7.4 Declining potable water supply and associated risk of water-borne diseases

Past and present adaptation measures

For some time now, communities in the Offinso District have realised the challenges posed by declining water security and associated health risks and have, consequently, devised some strategies to cope with the problem.

Communities in the district are combining indigenous knowledge acquired over the years, tampered with some behavioural change, to cope with the perennial water shortage. In addition to rainwater harvesting in barrels and other containers, most households ration water to reduce wastage (Gyampoh *et al.,* 2008). Most communities also have hand-dug wells as an alternative source of water (UNDP, 2007).

Proposed adaptation measures/activities

The strategies that communities in the pilot area have employed in the past (and at present) in dealing with declining potable water supply have not been entirely effective because the problems seem to persist. This is not because the strategies are flawed in substance, but because they have not been applied on scales which are adequate to resolve the problems in an efficient manner. The actions proposed in Table 11 represent a more refined strategy for more effective resolution of the problem.

Table 11: Proposed adaptation activities/measures to improve potable water supply and to minimise the associated health risks to communities in the Offinso District

<table>
<tr><th>Key vulnerabilities</th><th>Specific adaptation strategies/activities</th></tr>
<tr><td>1. Drying up of streams and scarcity of drinking water in rural, urban and peri-urban areas during the dry season.
2. Upsurge in incidence of malaria, onchocerciasis, etc.</td><td>1. Improve availability and access to water resources
• Increase sources of water supply. More boreholes and hand-dug wells should be provided, both at the household and community levels. However, indiscriminate drilling of boreholes could lower groundwater tables. A proper study on ground water resources and replenishment is a pre-requisite including an evaluation of accumulated effects, in case of a bigger scheme to use groundwater. This activity must be an integral part of the District’s medium term plans to ensure that communities can access clean water, and to serve as alternatives to other water sources such as rivers and streams which can dry up during drought.
• Improve water conservation measures: There should be improvement on existing water conservation measures to enhance water supply in the communities. Rooftop rainwater harvesting into big barrels and tanks must be encouraged at the household level to optimize the utility of available water. The District Assemblies and Community Development Units could also have innovative policy regimes, e.g., the construction of more rainwater harvesting structures in communities which will provide water during dry periods. Support other local efforts to increase the availability of water, and could even support crop production in the district. Additionally existing wells and boreholes can be rehabilitated and de-silted to improve the water situation in the district.
2. Protection of water catchments: Educational programs must be designed to raise awareness about effects of vegetation harvesting along river/stream banks. Communities must be engaged in tree planting along river banks to reduce siltation and help improve ground water recharge.
3. Improvement in public health surveillance:
• Public health surveillance techniques in the district must be improved to ensure fast and efficient distribution of items such as mosquito treated nets, and also providing vaccinations.
• Encourage community-based sanitation programs/primary health care. Communities must be encouraged to drain stagnant water, and also dispose of waste properly. Education and awareness creation on personal hygiene will also be necessary. Access to good primary health care is essential to improve resilience of local populations to water and sanitation related diseases.</td></tr>
</table>

8. Adaptation Strategies and Specific Activities in the Lake Chilwa Catchment

The Malawi government recognized that, since the climate is changing, the livelihood systems of the local communities must also change if the country was to avoid a catastrophe. This was manifested by the development of national climate change initiatives such as the National Adaptation Programs of Action (NAPA) in 2005 as a vehicle for implementing climate change adaptation and other related strategies. In the NAPA, it was explicitly stated that farming, fishing and forest dependent communities needed to adapt their livelihood systems. The changes that were needed were many and diverse. The adaptation strategies would happen at the local level, tailored to local circumstances and ecosystems, and chosen and managed by the communities themselves. It was recognized that the strategies should have both immediate and long-term benefits for the communities. These changes must be based on sound science, and enabled by effective policy at all levels and built on the wealth of knowledge that already existed.

In this section, therefore, past and present measures on adaptation related to forests and resource degradation within the context of the most important impacts on people in Lake Chilwa Catchment are discussed, and appropriate, concrete and specific adaptation measures that build on the existing local strategies are proposed to make them more effective.

8.1 Poor growth of planted trees on farm

The poor growth and yield of planted trees observed in the Lake Chilwa catchment, (Ngulube *et al*., 1999), is as a result of many and varied reasons at a local level. Some of the reasons reported (Ngulube *et al*., 1999) included poor species-site matching in which farmers planted tree species that were made available to them with little consideration of their site suitability; poor nursery management, e.g. most seedlings planted in the field were not root pruned at the nursery to enhance their survival in the field; emphasis on planting *Eucalyptus* species by many households and local institutions because of their fast growth and straight poles for construction purposes; water logging and dryness of some sites; lack of single tree management prescription i.e. most of the tree management advice provided to the farmers were based on management of forest plantations at a large scale.

These many and varied reasons reflect inadequate technical capacity of the communities in single tree management given the varied local conditions in the catchment. Therefore, and in order to enhance the productivity of planted trees in the catchment, the following adaptation measures (Table 12) are proposed.

Table 12: Adaptation measures to enhance growth and productivity of planted trees on farm in Lake Chilwa Catchment

Key vulnerabilities	Specific strategies/activities
Poor growth of planted trees on farm and around the homesteads.	1. Organise awareness campaign in schools and market days with drama performances on natural resource management 2. Prepare and distribute awareness flyers in Chichewa 3. Conduct residential technical training on single tree management on farm for volunteer community facilitators (VCFs). 4. Establish demonstration gardens (plots) and organize demonstration sessions for farmers 5. Organize farmer–to–farmer visits 6. Plant water logged tolerant tree species e.g. Tsambamfumu (*Afzelia quenzensis*) on water logged sites of the catchment and plant drought tolerant multipurpose tree species, e.g. neem (*Azadirachta indica*) on drier areas. 7. Protect the planted trees from animals, e.g. goats.

8.2 Loss of indigenous trees and woodlands on communal areas, riverbanks and surrounding forest reserves

The loss of indigenous trees and woodlands on communal areas, riverbanks and surrounding forest reserves in the catchment were mainly due to anthropogenic disturbances. Since the catchment is one of the most densely populated areas with an estimated 1.3 million people and a population density of 164 people per km^2 (National Statistical Office, 2008), the existing agricultural land is insufficient to support adequate food production for household needs. This is resulting in the opening up of new agriculture fields on the remnants of forests, wetlands and steep slope areas in order to expand the land requirements for crop production. In addition, indigenous trees are more preferred for use as firewood, charcoal and curio making, and for traditional medicine, etc; therefore trees and woodlands are over-exploited and the result is degradation of the landscape. The consequences of the degradation in the catchment are far-reaching because of the livelihoods' total dependence on these natural resources.

Table 13 provides adaptation measures that can be implemented in the catchment to enhance regeneration and protection of indigenous trees and woodlands in communal areas of the catchment.

Table 13: Adaptation measures to enhance productivity and conservation of indigenous trees and woodlands

Key vulnerabilities	Specific strategies/activities
Loss of indigenous trees and woodlands on communal areas, riverbanks and surrounding forest reserves	1.1 Participatory delimitation of priority indigenous woodland areas for regeneration and protection. 1.2 Conserve and regenerate indigenous woodland including riverbanks through protection. 1.3 Support to VNRMCs in the establishment of incentives and community policing for the protection of indigenous woodland and riverbanks.

8.3 Decline in productivity of agricultural crops

The declining productivity of agricultural crops is mainly due to declining fertility of the soils and undesirable cropping patterns of the local communities in the catchment. This is posing a threat not only for household food security, but also to the environment and natural resources of the catchment. As a measure to improve soil fertility, inorganic fertilizer application, use of compost manure, planting of nitrogen fixing trees in agroforestry systems, and soil and water conservation measures are implemented in the catchment. However, the adoption of these technologies by farmers is limited. Several studies have been conducted to assess drivers that enhance adoption of technologies by farmers in the catchment and surrounding areas. Based on these drivers and coupled with our findings in this study the following measures (Table 14) are proposed for implementation in Lake Chilwa catchment.

Table 14: Adaptation measures to enhance crop production in Lake Chilwa catchment

Key vulnerabilities	Specific adaptation strategies/activities
Declining crop yields	1.1 Organise awareness campaign in schools and market days with drama performances on soil and water conservation practices. 1.2 Prepare and distribute awareness flyers in Chichewa. 1.3 Conduct residential technical training on designing land conservation practices on farm for volunteer community facilitators (VCFs). 1.4 Establish demonstration gardens (plots) and organize demonstration sessions for farmers. 1.5 Organize farmer–to–farmer visits. 1.6 Increase crop diversification (e.g. cassava & potatoes). 1.7 Plant early maturing and/or drought tolerant crop varieties e.g. Hybrid maize varieties and new rice for Africa (NERICA) rice variety. 1.8 Promote/increase agricultural extension services.

8.4 Declining fish catch

The decline in fish catch in Lake Chilwa is mainly due to unselective catch of the fishes including juveniles; over-catch of the fish; increased silt loads and pollution from the cultivated cropland (Njaya, 1998). Many researchers have recommended a series of measures to increase fish production in Lake Chilwa. In our analysis we found that highest priority should be given to implement the following measures presented in Table 15.

Table 15: Adaptation measures to enhance fish production and catch in Lake Chilwa

Key vulnerabilities	Specific adaptation strategies/activities
Declining fish catch	1.1 Gill net fishery regulations should be enforced as most of the gill nets used in the lake have meshes less than 2¾ inches, which means that they target juvenile tilapia fishes 1.2 Setting of fish traps in rivers should be closely monitored, as it is observed that during the rainy season, *B. paludinosus* swim upstream for spawning and re-enter the fishery during the same period with many juveniles. 1.3 Promote fish culture within the Chilwa basin to ensure supply of fish at both household and national levels especially during the recessions. 1.4 Protect and conserve the steep slopes and other fragile upland areas in order to minimise surface run-off and subsequent silt load into the lake. 1.5 Train beach village committees in order to enhance their role in mobilizing local communities in lake management.

8.5 Declining potable water supply and associated risk of water-borne diseases

Since most of the rivers of the catchment spring from Zomba Mountain and snake through the urban areas of the Zomba City, the waters from the rivers are reportedly polluted with sewage wastes and other rubbish which are deposited into the river, particularly as they pass through the urban settlements. Consequently, the inhabitants of the basin largely depend on man-made water sources like boreholes, water taps, manually dug protected and unprotected shallow wells for potable water uses. However, not all these sources provide water throughout the year; most of them dry up during the dry months of the year, causing portable water shortages in the communities.

In addition, Masamba and Malwafu (2008) found that even the water from the boreholes, taps and protected wells had high levels of faecal coliforms and faecal streptococci, thereby not safe for direct human consumption. As a result of using unsafe water, the local communities suffer from waterborne diseases such as diarrhoea and dysentery, if the water is consumed untreated. Therefore the adaptation measures proposed are directed towards reducing the vulnerability of the communities from water shortages and subsequent water-borne diseases. These measures are presented in Table 16.

Table 16: Adaptation measures to enhance water supply and minimize risk of water-borne diseases

Key vulnerabilities	Specific adaptation strategies/activities
Declining potable water supply and associated risk of water-borne diseases.	1.1 Improve availability and access to water sources (e.g., hand-dug wells, boreholes, rain harvesting). 1.2 Boil any portable water before drinking. 1.3 Improve public health surveillance. 1.4 Promote community-based water and sanitation programmes/primary healthcare. 1.5 Strengthen public health education and awareness creation on personal hygiene, etc. 1.6 Protect water catchments through tree planting along river banks and awareness creation in local communities.

9. Conclusions

This study aimed at providing independent analysis and scientific information that is needed to develop effective projects on climate change adaptation in the context of rural Africa. Towards this end, IUFRO and its partners have worked through a longer process of scientific analysis, in order to arrive at concrete adaptation measures that can be implemented in the context of a specific rural situation. Major lessons learned in this process are briefly outlined below:

Three-tiered assessment approach: There are clear advantages using multi-level information on climate change as has been done in this study, ranging from the global, regional to the local levels. Because local climate data obtained from long-term measurements are scarce in Africa, it is important to utilise regional and global climate change results to arrive at realistic approximations on climate trends within a specific project area.

Involvement of local forest scientists: The assessments and analyses of the two pilot areas have clearly benefited from the fact that the local forest science community took the lead in conducting the study. Over decades, local forest scientists have been working in the pilot areas and over the years accumulated a wealth of information through a wide range of earlier studies, assessments and the implementation of development projects. This in-depth knowledge is vital for the identification of realistic adaptation measures that local communities are able to undertake in order to cope with changing climatic conditions.

Consultations with local communities: Besides the scientific work on the pilot areas involving the analysis, compilation, and interpretation of data and information, extensive consultations with communities are needed to come up with realistic adaptation measures. Although some consultations were held with local people in both pilot areas, it should be emphasised here that in this study there was insufficient time to comprehensively conduct the necessary social surveys and reconcile the proposed adaptation measures with the relevant local institutions and communities.

Degradation of natural resources: The analysis has shown that segregating climate change impacts from impacts on the environment that are largely caused by over-utilisation of the land is a difficult task. In the two pilot areas a complex mix of both factors have lead to significant degradation and even loss of forest resources. Therefore, most of the adaptation measures focus on reducing and/or reversing the degradation of forest resources and thus, building resilient and more productive forest ecosystems.

Identifying adaptation measures: The final step in the assessment process involves defining and elaborating concrete adaptation measures. Given the wide range of options available for adaptation, this step is all about setting priorities. During the process of defining these priority measures, extensive discussions were held among the participating scientists. One important lesson learned was that expanding existing adaptation measures already in use by local communities would be preferred over starting new activities that will take some time until their implementation can commence.

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