Climate change impacts for ecosystems management in Africa

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1.0 Introduction

Eight Fellows within the African Climate Change Fellowship (ACCFP) program Phase III, conducted research between November 2011 and July of 2012 and focused on climate variability and change across diverse ecosystems within the research theme of 'climate change and ecosystem management' (see Box 1). These researches included three forests (Kenya, Togo, Uganda) of which one was mangrove and two terrestrial; one coastal environment (Cameroon), a semi-arid rural area (Zimbabwe), a lake region (Chad); the energy sector in Togo and a laboratory experiment on soil fertility (Senegal). This paper is based on the eight case studies which are detailed as follows:

Box 1: Summary of case studies

Lake Chad

Lake Chad, a trans-boundary water body shared by four countries Africa is endangered and drying due to environmental degradation and declining rainfall catalysed by anthropogenic factors. The ACCFP project represented a phase that aimed to strengthen the lake and catchment's adaptation capacity using a learning approach, knowledge, understanding, analytical tools and best practices from Morocco using field visits and demonstrations that were carried out in different regions of Morocco.

Cameroon coastline

The coastal environment in Cameroon is endowed with natural resources with many investment activities such as fisheries, petroleum exploration and production and therefore human settlement. The ACCFP study determined the different climate change related impacts along the Cameroon coast and identified high risk zones as well as the potential risks to the various coastline inhabitants. The identification of the socio-economic impacts of the sea level rise on vulnerable coastlines and populations is important for timely actions to be taken in mitigating against the effects of natural disasters in coastal zones.

Kenya coastline

This study filled the knowledge gap in Mangroves in the East African region which support ~60% of the population through supporting, provisioning, regulating and cultural services. IPCC (2007) categorizes them as among the most vulnerable to climate change related effects such as sea level rise. Despite widespread studies globally, few studies have been reported in Africa and especially the link between climate change and mangrove provisioning of ecosystem services and goods in East Africa. In light of this, the ACCFP study in Tana, Kenya, investigated the functions and services of mangrove ecosystems in order to understand the drivers of mangrove status and in order to help adapt to and mitigate against the effects of climate change, especially for the coastal communities.

Senegal experiments

This study sought to address the various effects of climate change and its impact in Africa and particularly on plant growth and development and diminishing forests, by assessing the role of CgZF1 in the actinorhizal symbiosis in creating a process for effective inoculation with Frankia bacteria. In this regard, the

number of nodules, their morphology and functionality were evaluated in the She-oak seedling by over-expressing this marker in infertile soils. The knowledge generated will contribute to the understanding and usefulness of symbiotic nitrogen fixing models/species (ecological and / or agronomic) in the restoration of degraded ecosystems as well as the reforestation of endemic areas.In the long term the work will also contribute to climate adaptation via the transfer of new technologies in plant biology for improved adaptation to climate change namely symbiotic fixing capabilities of atmospheric nitrogen to cereals such as rice and millet.

Togo energy

The ACCFP study sought to provide an assessment of the vulnerability of the energy sector of Togo on the basis of appropriate climate models. This being essential in that it will assist in the formulation of appropriate adaptation and measures in time if the impacts of climate change on the biomass energy sector are to be minimized.

Togo forest

The study which focused on Abdoulaye Wildlife Reserve (AWR); in the Dahomey Gap, an interruption of forested of Guinean forests of West Africa classified as one of the world's 25 biodiversity hotspots addressed a research gap of data scarcity; thereby increasing the incongruousness for management planning and forest resources assessment of this protected area. The biodiversity investigations and inventories can provide a baseline for the national preparedness forests management policy; being key elements in preparedness of the Reducing Emissions from Deforestation and Forest Degradation plus (REDD+) credits project and the Clean Development Mechanism (CDM).

Uganda

Water from Echuya Forest Reserve (EFR) forms the main supply of most rivers and lakes in Kisoro, Kabale and the neighboring countries of Rwanda and the Democratic Republic of Congo while the forest itself is a biological diversity hotspot. The study therefore assessed the impacts of both climatic and non climatic factors on EFR and the communities' adaptation strategies. This research will increase the understanding of how to ensure sustainable conservation of the forest for the present and future generations.

Zimbabwe
The thrust of the ACCFP project was to assess the institutional frameworks for sustainable land management and climate change adaptation in Chivi communal area. In addition, the land use types and management, institutional frameworks and government efficacy in land management and climate adaptation were considered. This study helped reveal the institutional arrangements, policy interface(s) and social as well as economic organisation of marginalised rural communities in the face of environmental degradation.

2.0 African ecosystems

Africa is home to about 20% of the world's known biodiversity (Muller, 2009). The value of African ecosystems is without question, for they contribute significantly to livelihoods, poverty reduction and food security. They also provide habitats for living organisms, aid in regulating climate, floods and diseases; provide recreational benefits and cheap food sources mainly through animals, fish and plants and regulation of nutrients cycles and offer aesthetic and spiritual enrichment which contribute to both traditional and modern medicines as well as to economic development. The biodiversity has many direct economic values related to species that are bought and sold on the market (e.g. forest, fishing, and rangeland commodities), and many indirect values such as various kinds of outdoor recreation that do not require direct harvesting of species (Maroyi, 2009; Marunda, 1996). By far the most valuable of these indirect economic values are ecosystem services, defined as including regulating, cultural, provisioning and supporting services, which have been very undervalued by human societies.

Terrestrial ecosystems and forests provide various essential services, such as timber and paper, filtration of water, controlling of water runoff, soil protection, regulating climate, cycle and the storage of nutrients, and provision of habitat for innumerable animal species and recreational space. Aquatic ecosystems in particular provide potable water for human and livestock use, irrigation water for agriculture, a means of transportation of goods, generate hydro-electric power; and are a source of revenue from fishing and eco-tourism while their aesthetic value is invaluable.

The huge size of Africa (about 30.4 million km2) partly explains the diversity

of resources and environments that is characteristic of the continent. Africa's ecology can generally be classified into the humid (swamp and tropical forest), moist sub-humid (savannah woodland or guinea savannah), dry sub-humid (Sudan savannah), semi-arid (Sahel), arid and hyper arid zones. This divisions runs north and south of the equator except around the high Africa to the east. About 6.7 million km2 (23%) and 3.5 million km2 (12%) of Africa presently consists of forest and wooded land respectively (FAO, 2010). The forest and woodland extent is 27% and 20% in Eastern and Southern Africa region, 8% and 6% in Northern Africa region, and 32% and 9% in Western and Central Africa region respectively. The distribution of the forests according to purpose suggests that 30% of the total forested land area is for production, 14% for conservation of biodiversity, 17% for multiple uses and 3% for the protection of soil and water (this is lower than the global average of 8%).

3.0 Climate change and its impacts on ecosystems

Table 1 shows some of the major impacts of climate change and variability from the case studies. The most common of these are extended droughts, shifts in and more erratic (shorter) rainfall seasons, flooding and inundation and sea level rises; the latter particularly in coastal areas. In addition, deforestation and over harvesting of forest products are external factors that adversely affect ecosystem services and functioning. All these lead to reduced agricultural and natural resources produce and harvests particularly fish, livestock and staple crops, decreased incomes and, destruction of infrastructure to mention but a few of the cascading impacts. For instance, it was revealed that in 2010, the Kisoro District in Kenya was adversely affected by landslides where an estimated ~200 or more households were destroyed in five sub-counties. Thus, climate change and variability are an additional stressor among other stressors. Underlying causes of ecosystem degradation are highlighted as population pressure, use of new technologies in agriculture, unpredictable weather conditions and destruction of forest adjacent areas leaving the forest as the only alternative for most communities. The increasing demand for wetland materials by the communities has led to serious overharvesting and degradation of wetland resources.

Comparable climate variability and changes were recorded in Echuya Forest Reserve of Uganda. These included prolonged dry seasons, drought conditions, unpredictable, erratic rainfall and increased winds, disappearance of mists, La Niña and El Niño phenomena which are indicators of climate variability (see Appendix 1). The rainfall pattern was originally conducive for three

crop seasons hence making crop production possible all the year round but now only two planting seasons remain. As a result of the shift in winds and the rainfall cycles agricultural harvesting is now in January-February, June-July-August and in October than the previous July-August and December.

Table 1: Some common and major impacts of climate change and variability across the eight study cases

Climate variability & impact	Cameroon	Kenya	Lake Chad	Senegal	Togo energy	Togo forest	Uganda	Zimbabwe
Climate Extremes								
1. Extreme heat		X	X					X
2. Strong winds	X	X					X	
3. Extended droughts		X	X				X	X
4. Flooding and inundation	X	X						
5. Sea level rises	X	X						
6. Shifts in long and short rainfall seasons			X		X	X	X	X
Ecosystem functioning and services								
7. Biodiversity loss	X	X				X	X	
8. Invasive species encroachment		X					X	
9. Reduced fish production/catch	X	X	X					
10. Sediment deposition	X	X	X					
11. Land/Mud slides							X	
12. Reduced water for agriculture/ consumption			X				X	X
Economic and human capital								
13. Loss of property/houses	X	X					X	

14. Poor harvest, crop failure and food shortage		X		X			X	X
15. Reduced incomes		X					X	X
16. Reduced food security	X	X		X			X	X
Health/Increase in diseases spread and prevalence								
17. Malaria	X							
18. Meningococcal meningitis	X							
19. Cholera	X							
Non-climatic factors								
20. Deforestation	X	X	X		X	X	X	X
21. Increased/ overharvesting of forest products	X	X					X	X
22. Unsustainable farming/ land use practices		X	X					X

According to the Chivi (Zimbabwe) community perceptions, the major evidence associated with climate change are droughts, shifts in rainy seasons namely delayed onset and shorter season; increasing temperatures, prolonged winter season and decreasing annual precipitation. It was claimed that the winter season has been prolonged to August and the rainfall season has shifted from October to November and December and that the delayed onset of the rainy season has shortened the rainfall seasons. Shongwe (2011) observed also that the stimulated annual cycles in a warmer climate had a one month delay of the rainfall on-set and no shift in rainfall cessation months, thus implying shorter rainy season. According to Scoones (1996), within years, rainfall is also highly variable and the coefficient of variability for rainfall in Chivi District during the month of January is 78%, with about 45% of years experiencing rainfall at least 25% longer than the long term average.

These changes, coupled with human influences have resulted in biodiversity loss, reduced ecosystems services and low rates of forest regeneration, poor harvests, crop failure and food shortage, fluctuations in water levels particularly reduced water level for animals and communities, colonization of invasive species as well as land/mudslide which destroy households and can claim lives. A classic example of water level fluctuations is Lake Chad which has shrunk from about 24 000 km2 in the 1960s, to the current variation of between 2000 and 1700 km2.

Climate related events such as sea level rise, extended drought periods, flooding and massive sedimentation have also been shown to affect mangroves (Gilman et al., 2008). Two catastrophic phenomenon which were noted among mangrove areas along the Kenyan coast include the 1997/98 and 2006 El Niño which caused massive sedimentation causing dieback of mangroves (Kitheka et al., 2002, Bosire et al., 2006, IPCC, 2007; 2014). Since mangroves in Tana River delta occur in low lying land, a small increase in sea level results in mangrove submersion and need for communities to migrate to new areas mainland (Huxham et al., 2010). Sea level rises have led to farmers in this area experiencing salt infiltration into their farms, an occurrence they had never witnessed before. This is perceived not only as a result from rising sea levels but also due to the fact that the mangrove vegetation along the coast has been degraded through deforestation. The prevailing climate-related hazards facing the community, as well as their corresponding impacts were mentioned as follows: drought which led to increased agricultural output, low fish catch, reduced grazing

pasture and water for livestock, prevalence of diseases, reduced business and accelerated household food security. Extreme heat and increasing sea turbulence conditions were also mentioned as having led to disease prevalence, reduced fish catch, loss of fishing equipment, low agricultural produce and water scarcity. Strong winds were noted to be common in the Delta and this has led to incidences of capsizing of fish vessels, reduced fish catch, livestock illness, tree uprooting and damage to homesteads (See Appendix 2).

4.0 Adaptation and climate change knowledge, awareness and institutional policy issues

Climate change is one among many other elements of global environmental changes that bedevil livelihoods. Risks associated with climate change and climate variability are evident and are one of the emerging socio-physical challenges (IPCC 2007, 2014). The Cameroon coastline for instance demonstrated that the area is high risk to climate change with close to 50, 000 inhabitants classified to be at high risk. The changing climate potentially has negative repercussions on livelihoods given communities' dependence on natural resources and rain-fed agriculture. Thus, there is a renewed cause for concern with regards to livelihoods especially in the area of food security, that has traditionally been achieved through own production. Adaptation measures and strategies were reflected in all eight case studies.

Institutional arrangements, players in climate adaptation

A general trend among smallholder farmers in Africa is that they have over the past decades continued to rely on simple technologies and external support from government agencies and non-state actors (Long, 2001). Most of the rural customary areas in Sub-Saharan African countries are located in arid and semi-arid areas, making the rural communities, most of whom are smallholder farmers, especially vulnerable to both socio-economic and biophysical challenges. This was clearly demonstrated across all case studies but especially in the Chivi District of Zimbabwe where several actors and players are involved in climate change adaptation which involve both the state and non-governmental as well as community based organisation (NGOs and CBOs), traditional authorities as well as norms and values. In Chivi the players include the Environmental Management Board (EMA), Forestry Commission, Rural District Council (RDC) traditional and village heads, chiefs and agricultural extension services as the main state

organs and several NGOs that are responsible for the implementation of agriculture, conservation, land and water management adaptation policies in the form of government and traditional by-laws, traditional customs, norms and values, projects and programs. However, these and in particular the state layers face a number of challenges. For instance, there is poor coordination among government departments at a local level while the recent empowerment of village heads to allocate land in the communal areas has resulted not only in stream bank cultivation but also in wetlands and valleys. Similarly, this was also experienced in Echuya Forest Reserve (Uganda) where previously cultural values such as the upholding of 'sacred places', a traditional way of conserving biodiversity and wetlands have broken down leading to cultivation of wetlands and decreased biodiversity in and around the forest.

Coping strategies and health

Coping strategies in Echuya (also detailed in Appendix 2) like most communities in the continent involve diversification of livelihoods and included beekeeping, oyster mushroom production, vegetable, Irish potato growing among others. In addition, the Batwa use dance and drama to gain some income in order to supplement firewood collection and water fetching that have been practiced for years. This also assists them to increase their capacity to build semi permanent houses to shelter them during periods of unpredictable weather. In Kenya, while some of the coping strategies used by the community work effectively in the short-term (such as seeking medical attention for climate-induced illnesses, moving in search of livestock grazing grounds and water and engaging in subsistence agriculture), none of the strategies are sustainable. For fishermen turning to in-shore fishing during the turbulent periods at sea means over-crowding in the limited fishing grounds thereby exerting much pressure on the fisheries. In Cameroon, climate change adaptation measures were mostly related to modifying the local architecture designs of houses in the form of building suspended houses and raised floors along the coastline while in Uganda houses were modified from mud and thatch to bricks and mortar roof sheets to prevent extensive damage by flooding, land and mud slides.

Major constraints in the health sector of the Cameroon coastline were identified as insufficient amounts of human, material and financial resources. Although Cameroon has an early warning system for cholera and meningitis epidemics, it was acknowledged as not fully operational due to lack of trained personnel.

Communication and knowledge sharing

Across the case studies effective communication of climate science, climate change, impacts and adaptation and mitigation was shown to be crucial. In Cameroon for instance, though over half (57.4%) of the people interviewed across the coastline reported that they were not aware of climate change with the exception of the Kribi -Campo area (probably due to its accessibility and preferred location for many seminars and workshops by the government and NGOs); they were still able to respond to some questions on the subject. Thus climate awareness plays a crucial role in availing information and enhancing understanding of climate change and variability. For example, a good communication network of radio and television channels in the Kribi-Campo area also serve as a medium of sensitization. Direct intervention in the domain of climate change includes sensitization actions, measurement of carbon emissions, development and implementation of climate change adaptation measures. Indirectly, some institutions intervene through the allocation of funds, building of smoke houses, use of animal dung as energy source and tree planting. Some of the projects offered by these organisations involve agriculture, carbon inventory, carbon trading, CDM improved smoke house, community forests, environmental education, forest conservation, mangrove reforestation, and resilience, aforestation, REDD, REDD subsistence agriculture trade-off, research sensitizations on participatory wildlife monitoring, conducting EIAs, evacuation and provision of temporal accommodation, policy improvement, mangrove wood energy use efficiency, reduction of carbon footprints, research and mangrove carbon inventory.

Policy

Similarly, in Echuya Forest Reserve in Western Uganda, a number of organizations are involved in climate change adaptation. In terms of policy, the state of Echuya forest ecosystem is critical due to lack of proper protection from the government. The Batwa are dissatisfied with government efforts as well as development agencies operating in the area, hence regarded the current state of ecosystems as unsustainably managed. They indicated that instead of conserving the Echuya for continuous use, the government was only interested in collecting revenue from sell of forest products especially green bamboo and timber.

Like many African countries such as Zimbabwe, Cameroon does not yet have a climate change policy, but rather, this is enacted in a number of laws and decrees that contain specific measures that can help combat climate change. There is a need to harmonise the loose pieces of

legislation and their implementation on the ground for a consented effort towards adaptation measures. In Kenya in terms of policy, the absence of cutting plans in the current licensing system means that there is no system of checks to ensure sustainable extraction by the licensed wood cutters. Consequently, the cutters use indiscriminate cutting methods leading to over-harvesting and also reduction in quality of the forest due to their preference to straight poles. This explains the differences in size-class distribution in Tana Delta mangroves as well as the low complexity index of the forest. This is because they do not have a protected status (Riungu, 2009) unlike others that occur within marine protected areas therefore increasing their vulnerability to human engineering. Its open-access status has led to massive over-exploitation and degradation (Kairo 2005). These twin issues pose challenges to their management as well as sustainability of restoration programs.

In contrast, Togo has an updated energy policy. The effective implementation of current energy policies would enable Togo to save 122.6 million GJ of wood energy between 2010 and 2100, or 35.2 million GJ for charcoal and 87.4 million GJ for firewood. According to FAO (2009), 1 kg of charcoal is equivalent to 6, 65 to 7.8 kcal and 1 kg of firewood provides 3.3 kcal. On this basis, the implementation of energy policy will save approximately 1,270,676 kg of charcoal and 6,363,636 kg of firewood between 2010 and 2100. This will greatly reduce the pressure on wood resources which are in continuous degradation. Policy scenario of fuel wood demand shows that more than one million kilograms of charcoal and more than 6 million kilograms of firewood could be saved by 2100. The policy scenario of the potential of wood energy also indicates an increase in the availability of fuel wood of more than 3.6 million m3 by 2100. These two scenarios show the importance of good planning of activities both in the production of wood energy and the consumption level. As for production, it is urgent to disseminate new production technologies that are cost effective and environmentally friendly such as the Casamance improved production. It is a technique that increases char yield from 15% (Thiam, 1991) to 3035% (MECV, 2005). With this technique deforestation could significantly be reduced by almost 25% (Ducenne, 2001) and thus increase the availability of wood energy. In addition, there is need for extension of forest cover as defined in Togo's National Forestry Action Plan (NFAP 2011). At the consumer level, the dissemination of improved stoves and encouraging consumption of butane gas as defined in the energy policy of Togo (PET, 2012) are urgent actions to be implemented. Butane gas should be popularized in

urban areas in order to reduce the consumption of charcoal as 80.2% of urban households use charcoal against 17% of rural households (DGSCN, 2006). The improved stoves should in turn be disseminated in both urban and rural areas.

Wood energy and reforestation

One of the major impacts or rather exacerbations by climate change is on rural livelihoods and in particular the sources of energy which is mostly wood in rural areas. This has led to increased pressure on natural resources and more so forest ecosystem services and products as well as unsustainable land use practices. Similar to the Togo case which is losing 5.1% of its forest cover net per year (FAO, 2010); in Chivi, there is rampant cutting of wood as this source forms 90% of the energy source and there are no alternate sources of energy in these rural areas. Wood is also used secondarily for wood carving and firewood selling. Locally perceived causes of land degradation showed that half (50%) of the respondents associate land degradation to poor farming methods, 38.6% to deforestation, 9.3% to shortage of grazing land and 2.1% to gold panning. Approximately thirty nine percent (38.6%) of the respondents considered degradation of land to be caused by firewood production.

Similar to the scenario in Togo, Chimhowu (2009) found that the demand for fuel wood has led to high deforestation in communal areas because of lack of alternative energy sources. In Zimbabwe, deforestation accounts between 100,000 and 320,000 hectares per year as more land is being cleared for commercial firewood production (Cotula et al., 2009). In the study, about 77.9% cut down trees for wood energy, 5.7% poles for construction, 1.4% wood carving and 15% for firewood production for commercial purpose. Most people indicated that the reason why they continue using wood as their source of energy due to unavailability of alternative energy sources. According to the Government of Zimbabwe (2008), wood-fuel accounts for over 90% of the total energy requirements of the rural communities and almost 15% of this amount comes from forest depletion. This depletion is also accelerated by the demand for indigenous building materials, natural forest fires and the resettlement exercise. Sadly, it is mostly the elderly (>45 years) who practice aforestation and also have time to do it though they are constrained by long distance and lack of energy to carry water (4km) to nurseries in Chivi.

Similarly, in Uganda, the community practices agro-forestry and tree planting which have proved to be the best alternative to forest derived resourc

es hence being considered as both community mitigation and adaptation strategies. Consequently they also act as an alternative source of food, beans stakes, firewood, and construction material for income as well as soil and water conservation. In this the community has been supported by a number of organizations such as Africa 2000 Network-Uganda, Nature Uganda in collaboration with Kulika Charitable organization through training courses and provision of seedlings. In addition, other projects that aim to reduce the rate of forest degradation have included bamboo domestication and promotion of indigenous, agroforestry species in the area that include Venonia, (locally known as umubirizi) as well as exotic ones like Calliandra grevellea, Tephrozia alnus, Sesbania sp. and avocadoes. This also helps improve soil fertility as well as soil and water conservation. However, the rates adoption of this strategy by the Batwa is still low since most of them do not own land.

5.0 Challenges and opportunities faced in adaptation

Lack of long-term data and monitoring systems

One of the major challenges faced by Africa is the lack of continuous, systemic data on ecosystems that can provide a baseline for monitoring programs, policy and intervention. The general conclusion from the studies is that new innovative methods are needed, given the lack of data. It is also suggested that basic indicators of vulnerability of communities and ecosystems to climate change and vulnerability be developed. The few vulnerability assessments like the one along the Cameroon coastline and the Togo energy sector with adaptation plans point to the need for ecosystems protection, reforestation with “climate-smart adaptations,” integrated land-use and development planning cognisant of environmental protection, as well as activities to improve resource use technology.

Reliable, long-term, systemic research and data on woody species diversity of both terrestrial and mangrove forests are required to minimize data scarcity and lack of consistency for research-based policy decisions. This is because Africa’s forests cover is dwindling (FAO, 2010). The Togo Abdoulaye Wildlife Reserve forest study in this regard attempted to fill the research gap by providing above ground biomass, woody species diversity and consequently potential carbon cycling which is often scarce in most ecological studies which rather typically focus on forest diversity assessment and structure without consideration of biomass measurements and carbon cycle.

Provision of renewable sources of energy

One major challenge for Africa is the provision of renewable sources of energy. As demonstrated in the Togo energy sector case and in Uganda and Zimbabwe, most of the methods used for collecting wood and developing charcoal burning are archaic with yields of about 15% of energy (Thiam, 1991; Girard, 2002). This is a very high source of waste of wood products resulting in the cutting down of many trees. Charcoal burning alone causes deforestation at a rate of about 5,000 hectares per year in Togo (MEMEPT, 2002). Today, the increasing rate of deforestation is a great concern in many African countries like Togo that is not a forest country unlike countries in the sub-region such as Ghana, Cote d'Ivoire and Nigeria (White, 1986), which are located at the same latitudes.

Despite this, many African countries have been able to stabilize their forest areas with Tunisia, Morocco and Rwanda report the largest increases in forest area between 2005 and 2010 (FAO, 2012); thus lessons learnt and best practices there can be used in similar scenarios. The availability of biomass energy in the coming decades will be severely compromised if appropriate adaptation options are not developed in time and appropriate measures taken to curb the effects of climate change on the biomass energy sector and streamline its operations. The Togo forest policy and future projects and scenarios provides an excellent example of ways to communicate the depth of this issue in a way that policy makers can grasp and understand. However, this is in cognisance of the fact that most African governments are battling with resources, planning and implementation of policies for the 'now' let alone futuristic and particularly mid and long-term future periods.

Loss of biodiversity and invasive species

A separate challenge of climate change and variability is the loss of biodiversity. Climate-induced loss of natural habitats, environmental degradation, coupled with effects of increasing population pressure, change in consumer demand development and use of a few species, varieties and breeds are also some challenges that adversely affect biodiversity. This was reflected in Echuya Forest Reserve where the use of birds for spiritual rituals has led to their significant decline. In addition, the forest reserve which consists of mainly three distinctive ecosystems namely: Bamboo, high altitude or montane swamps and mixed shrub/woody forest, is threatened by overharvesting and invasive species which have also exacerbated the rates

of ecosystem degradation. In Kenya, the tree species, Avicennia marina dominated in the study area in stem density and regeneration. This species is known to tolerate a wide range of environmental conditions (Dadouh-Guebas et al., 2004; Huisman et al., 2009; Wang'ondu et al., 2010) and therefore is always a pioneer species in case of degraded and exposed areas with extreme conditions. Low regeneration of other mangrove species as well as low recruitment to higher size classes may be indicative of directional changes related to changes in the Tana River flooding regime. This flooding caused by high water events having potentially impeded seedling recruitment and establishment (Sousa et al., 2007; Gilman et al., 2008).

6.0 Opportunities presented by climate change and variability

Despite the challenges, many opportunities are presented for research and implementation to enhance climate change adaptation. Opportunities can focus on diversification of livelihoods which hinges on natural resources management and the concepts of inclusive benefit sharing from biodiversity, community based natural resources management (CBNRM)-like initiatives, indigenous knowledge systems and biodiversity conservation, knowledge generation and sharing, access and benefit-sharing as well as use of business models to enhance benefits from land, water and other natural resources which can e achieved through advocacy and promotion of integrated conservation and management systems between (Mutasa and Ndebele-Murisa, in press).

Other opportunities presented through the studies were areas for further research and development as well as matching of existing, archaic policy to prevailing climatic conditions, including the setting up of institutions that take into account the volatility of climate change. For instance in Chivi (Zimbabwe) the current soil and water conservation techniques advocated for such as ridging to reduce water clogging in fields when there is now more of water shortages in and around the area and therefore need to retain water do not fit current climatic conditions. There is also a need to improve access, benefit sharing and awareness of conservation and environmental protection. Costs of conservation farming (labour, digging basins, searching for organic fertilisers, mulching, weeding) can be reduced through assistance as these in some cases far outweigh the benefits and are exacerbated by youth migration and climate change, impacts of HIV and AIDS on population, lack of knowledge

and capacity (support) by extension workers as was revealed in Zimbabwe.

Other opportunities include the development and implementation of both soft and hard technologies, innovations and invention for climate adaptation and mitigation. For instance, the continuous occurrences of unpredictable weather conditions and related effects which include complete or partial destruction of huts, crops, beehives and other property and scarcity of firewood due to reduce quality caused by persistent wetness have forced Batwa and other institutions supporting them to change the traditional hut designs to come up with modified ones. In another instance, the Senegal experiments showed that it is possible to reforest Africa using She-oak as a result of its low seedlings mortality. Moreover, these seedlings are robust and grow very fast. These new technologies in plant biology for improved adaptation to climate change which focused on the role of symbiotic nitrogen fixing models species (ecological and / or agronomic) in the restoration of degraded ecosystems can in the long term contribute to the transfer of symbiotic fixing capabilities of atmospheric nitrogen to cereals such as rice and millet. Giving that these are the staple foods for the people of West Africa, particularly in Senegal, it would lead to food security. These two examples reflect that there is a great need and opportunity to invest in research and development of several varieties of crops, livestock and fisheries development as well as increasing soil fertility in tandem with the changing environment.

A good example of a livelihood diversification strategy would be fish farming. To date African policy and development practice has paid scant attention to smallholder pond based fish farming as a form of livelihood and yet the continent could feed itself within a generation through the application of innovative, science-based yet simple technologies to agricultural production such as small-scale pond fish farming that can be adopted in both rural and coastal areas. Recent studies have shown that small-scale aquaculture development brings about positive changes and implied benefits, particularly if practised concurrently with and complementary to crop and livestock production (FAO, 2009; Hempel, 2006; Tongowona, 2009). Other innovations may include promoting carbon sequestration through reforestation and mulching crop diversification and rotation as measures Africa can rely on to promote a climate resilient agriculture and practices such as conservation tillage and irrigation which will help address the deficit of water that climate change is bringing (Twomlow et al. 2009). Solar energy and the inclusion of biofuels is an opportunity that could

help reduce the energy deficit in African agriculture (Yanda and Mubaya, 2011).

All these recommendations spell out opportunities for research and implementation and particulaly the conservation of land, water and forest resources.

7.0 Discussion and conclusions

The nexus between ecosystems and development is very graphic across Africa because much of state economies and rural livelihoods rely heavily on the ecosystems and natural resources stock. Compared to the developed economies of the world resource conversion and value additions generally tend to be low and livelihood diversification is narrow. Over-reliance on the natural resource systems induces multiple stressors that are exacerbated by climate change. These stressors increase the vulnerability of populations and stretch the traditional resilience of African societies to the limit. Schneider et al. (2007) describe the vulnerability to climate change as the degree to which the geophysical, biological and socio-economic systems are susceptible to, and unable to cope with, adverse impacts. Poor infrastructure and technology, poverty, poor dissemination and use of climate information and weak resilience and adaptive capacity tend to crystallize these vulnerabilities into complex interconnectivities that perpetually overwhelm the majority of the population. This was the case with the Batwa of Uganda, a traditional minority group in Western Uganda and in Cameroon where poverty is more preponderant in rural areas and the incidence is estimated at 74.3% being higher in the savannah regions (92.5%), slightly less in the Central (84%) and Kara (80%) regions of that country.

African water resources namely lakes, wetlands and estuaries are sensitive to climate warming, as they experience wide fluctuations in temperature across seasons and over a wide spectrum in the frequency and magnitude of droughts and flooding. Much of what is happening to freshwater resources across Africa is attributable to years of drought that reduce river inflows, and rising temperatures that cause increased evaporative water loss while in some areas excess water due to increasing rainfall and flash rains is resulting in floods, land and mud slides (Arnell, 1999, 2004). The extreme example is Lake Chad, once the world's sixth-largest freshwater resource, which has decreased to 5% of its original size of approximately 25 000 km2 in 1963 to 1 350 km2 in 2001.

This is attributed to large and unsustainable irrigation projects built by Niger, Nigeria, Cameroon and Chad which have diverted water from the freshwater resource as well as from the Chari, Logone and Niger Rivers, major overgrazing in the region resulting in a loss of vegetation, and serious deforestation contributing to a drier climate (Carmouze et al., 1983; Coe and Foley, 2001). The changes in the Chad also pertain to a marked variability in the hydrological regimes of the rivers that feed it, as well as rainfall regimes in the region, worsened by population pressure, low environmental awareness levels and the absence of sustainable development in the political programs of the riparian countries. This has led to continuing decline in local access to water, crop failures, livestock deaths, collapsed fisheries and other wetlands services. Other examples of African freshwater resources that may be responding to increasing temperatures driven by climate change are Lake Turkana, which is the largest, most northerly and most saline of Africa's Rift Valley lakes, whose level has dropped 10m between 1975 and 1992 due to reduced inflow (McGinley, 2008), and Lake Victoria, whose level has dropped over 1.5m in five years (Phoon et al., 2004; Awange et al., 2008) as well as Lake Chilwa in Malawi which has dried up completely in recent years (Jamu et al, 2010).

Africa has traditionally been vulnerable to desertification and droughts. In the Sahel region that extends from west to east Africa and in parts of north and southern Africa, low rainfall coupled with high temperatures has always been a traditional limiting factor for human livelihood. The inhabitants of these low rainfall zones have had to develop some adaptive capacities and ingenuities to manage and maximize their land and water resources for centuries. These include traditional precision agriculture that take advantage of location and seasons as well as soil and ecosystems management techniques that enable them produce just enough to survive the times. However, climate change has indeed accelerated and exacerbated the frequency of drought and rate of desertification and the traditional resilience and adaptive capacity is being outstripped. The adaptive capacity of the Lake Chad catchment area for instance is very low and is reflected in the shrinking lake and dwindling provision of its ecosystem services.

The long lasting impacts of drought on national economies of Africa, and the loss of human and herd animals from recurring and persistent droughts in the countries around the horn of Africa including Ethiopia, Eritrea, Djibouti and Somalia, the regular famine and food shortages in the Sahelian countries

especially Niger and Somalia and the general poor nutrition profile of many countries of Africa are clear testimony to the tragedy of the challenge posed by climate change. Droughts have generally become more frequent while the rate of desertification or encroachment of the arid condition especially into the savannas of West Africa is alarming. The case of deforestation across Africa has been discussed. Changing forest conditions has been projected to cause species changes and complete loss or displacement of endemic plant distribution including the Karoo biome and Fynbos. Deforestation and removal of woodlands and loss of forest quality in west, central, southern, eastern, and western Indian ocean coastlines of Africa has and will continue to have tele-connection effects including change in moisture fluxes and reduction in rainfall in other parts of Africa which will exacerbate the food insecurity conditions if conditions remain the same. Though desertification was limited to the Chivi case study, many of the factors including drought and particularly deforestation were reflected in all the eight case studies as they all relied on forest resources to a large extent and deforestation was shown to be rampant.

Sea level rises and flooding of coastal cities in Africa is a big challenge to the liveability of these cities. Millions of population live in slums and informal settlements in marginal areas such as floodplains, near natural wetlands and mangrove forests. This situation is projected to get worse in future due to climate change induced sea level rise. An accelerated sea level rise induced by climate has the potential to spell disaster in coastal areas due to large populations that settle along the coast. This was the case with both the Cameroon and Kenyan coastline communities which are highly vulnerable to climate changes and variability.

8.0 Recommendations

• Generation of income and alternative or diversified forms of livelihood of people is advocated for;

• In addition, it is important to enhance the policy and institutional capacity to promote conservation and climate adaptation. This may include the establishment of community-based conservation / resource management committee at key villages, capacity building for state departments, NGOs and CBOs, development of eco-tourism and eventually sharing the work plan with the stakeholders through consultation, discussion and workshops;

• There is need to seriously develop actions for reforestation, restoration and development of the degraded forests (both mangroves and terrestrial forests);

• Public education campaign must be conducted to make local communities, the tourism industry and other sectors aware of the importance of ecosystems. It is imperative to inform, educate and train community for their acceptance, buy-in and engagement in the policy-enforcing actions.

• In most African forests and hotspots, conservation strategies to protect woody species against anthropogenic factors (for example, protection from or reducing the frequency and/or intensity of disturbance, especially wood-cutting and bushfires) should be taken to increase the abundance of rare species. Successful forest sustainable management implies the involvement of stakeholders, scientists with full agreement and participation of local communities. Formulation of adaptation options will require prior assessment of the vulnerability of the sector on the basis of appropriate climate models.

9.0 References

Adjonou K., Ali N., Kokutse A.D., Segla K.N., Kokou K. 2010b. Etude de la dynamique des peuplements naturels de Pterocarpus erinaceus Poir. (Fabaceae) surexploités au Togo. Bois et Forêts des Tropiques

Adjonou K., Djiwa O., Kombate Y., Kokutse A.D. and Kokou K. 2010a. Etude de la dynamique spatiale et structure des forêts denses sèches reliques du Togo: implications pour une gestion durable des aires protégées. International Journal of Biological and Chemical Sciences 4 (1): 168-183

Arnell N.W. 1999. Climate change and water resources. Global Environmental Change 9: 31-49

N.W. 2004. Climate change and global water resources: SRES emissions and socio-economic scenarios. Global Environmental Change 14: 31-52

Awange J.L., Sharifi M.A, Ogonda G., Wickert J., Grafarend E.W. and Omulo M.A. 2008. The falling Lake Victoria water level: GRACE, TRIMM and CHAMP satellite analysis of the Lake Basin. Water Resource Management 22: 775-796

Boko M., Niang I., Nyong A., Vogel C., Githeko A., Medany M., Osman-Ela sha B., Tabo R. and Yanda P. 2007. Africa. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry M.L., Canziani O.F., Palutikof J.P., van der Linden P.J. and Hanson C.E. (Eds). Cambridge University Press, Cambridge UK, 433-467

Carmouze J.P., Durand J.R. and Lévêque C. 1983. Lake Chad. Ecology and productivity of a shallow tropical ecosystem. Monogr. Biol. 53. Dr W. Junk Publishers, The Hague

Chagutah T. 2006. Environmental reporting in the Zimbabwean press: A case of the Standard and the Sunday Mail. Unpublished MA dissertation, University of Zimbabwe, Zimbabwe

Chimhowu A. 2009. Moving forward in Zimbabwe, Reducing poverty and promoting growth. The University of Manchester Brooks, World Poverty Institute

Colfer CJP, Sheil D., Kaimowitz D. and Kishi M. 2006. Forests and human health in the tropics: some important connections. Unasylva 224: 3-10

Cotula L., Dyer N. and Vermeulen S. 2008. Fuelling exclusion? The biofuels boom and poor people's access to land. IIED, London

Dhliwayo M. 2007. Human rights and climate change, Chivi case study: Zimbabwe Environmental Law Association, Harare

Ducenne H. 2001. Rapport première mission visant l'amélioration de la carbonisation dans les zones d'interventions de l'Agence Energie Domestique Environnement (AEDE) en périphérie de N'Djamena

Ern H. 1979. The Vegetation of Togo. Gliederrung, Gefährdung, Erhaltung. Willdenowia 9:295-312

Food and Agricultural Organisation (FAO) Aquasat 2009. FAO's information system on water and agriculture - Country profile Zimbabwe. Version 2009. Accessed at http://www.fao.org/nr/water/aquastat/countries/zimbabwe/index.stm

FAO 2010. Global forest resources assessment. Main report, FAO Forestry paper 163, 340 p. www.fao.org/docrep/013/i1757e/i1757e.pdf

Girard P. 2002. Charcoal production and use in Africa: Wath future? Unasylva 211: 30-34
18. Government of Zimbabwe 2008. Zimbabwe Millennium Development Goals 2000-2007 Mid-Term Progress Report. UNDP, Harare, Zimbabwe

Hassan R 2006. The double challenge of adapting to climate change while accelerating development in sub-Saharan Africa. Environment and Development Economics 15: 661–685 C Cambridge University Press

Hijmans RJ, Cameron SE, Parra JL, Jones PG, Jarvis A (2005). Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology 25:1965-1978

Hirji J, Maro P and Chiuta TM 2002, Defining and mainstreaming environmental sustainability in water resources management in southern Africa. SADC, IUCN and SARDC

Intergovernmental Panel on Climate Change (IPCC) 2007. Freshwater resources and their management, in Parry M.L., Canziani O.F., Palutikof J.P., Van der Linden P.J. and Hanson C.E. (eds.). Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK. Pp 976

Intergovernmental Panel on Climate Change (IPCC) 2013. Summary for Policymakers, in Alexander, L. et al. (drafting authors.). Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK

ITTO 2005. Revised ITTO criteria and indicators for the sustainable management of tropical forests including reporting format. ITTO Policy Development Series No 15, Yokohama, JAWRn, p.39.

ITTO/IUCN 2008. Guidelines for the conservation and sustainable use of biodiversity in tropical timber production forests. ITTO Policy Development Series No. 117. Yokohama, JAWRn. p.118

Jarvis A, Reuter HI, Nelson A, Guevara E (2008). Hole-filled seamless Shuttle Radar Topography Mission (SRTM) data V4, International Centre for Tropical Agriculture (CIAT), available from http://srtm.csi.cgiar.org

Kokou K, Atato A, Bellefontaine R, Kokutse AD, Cabbale G 2006. Diversité des forêts denses sèches du Togo (Afrique de l'ouest). Revue d'Écologie Terre et Vie 61(3):225-246

Koziell I. and Saunder J. (eds.). 2001. Living off biodiversity: exploring livelihoods and biodiversity issues in natural resources management. International Institute for Environment and Development, London

McNeill C. and Shei P. 2002. A framework for action on biodiversity and ecosystem management. WEHAB Working Group, WSSD, Johannesburg

MECV, 2005. Document d'orientation de la production du charbon de bois au Burkina Faso. Ministère de l'Environnement et Cadre de Vie MEMEPT, 2002

Millennium Ecosystem Assessment (MA). 2005. Ecosystems and human well-being: biodiversity Synthesis. World Resources Institute, Washington, DC

Mtisi S. 2010 LEAPS and Climate Change: Opportunities for Industry: University of Zimbabwe

Müller C. (2009). Climate change impact on Sub-Saharan Africa : an overview and analysis of scenarios and models Bonn : DIE, 2009 - (Discussion Paper / Deutsches Institut für Entwicklungspolitik 3/2009

Mutasa M. and Ndebele-Murisa M.R. (In press). Biodiversity and human development nexus- conservation, utilisation and sustainability. In, Murisa T. And Chikweche T. (Eds). Zimbabwe in the next ten years

Myers N., Mittermeier R.A., Mittermeier C.G., da Fonseca G.A.. and, Kent J. 2000. Biodiversity hotspots for conservation priorities. Nature 403: 853-858

Neba Aaron, (1999) Modern Geography of the Republic
of Cameroon, 3rd ed. Bamenda: Neba Publishers.

Appendix 1: Adaptation strategies used by the Batwa in Echuya Forest Reserve, Uganda (in no order of importance)

- Formulation and development of by-laws
- Use of inorganic fertilizers and agro-chemicals
- Agro-forestry and tree planting
- Income generating activities
- Redesigning houses- bricks and mortar roof sheets
- Gravity floe extension to (some) households
- Use of rainwater harvesting tanks and jars
- Bee keeping
- Use of bamboo water
- Use of lakes and reservoirs as a source of domestic water supply
- Dancing and working for income and food
- Resettlement near Echuya Forest Reserve
- Promotion of livelihood improvement initiatives (crop cultivation and livestock rearing)
- Begging for survival
- Sale of forest income
- Guarding crops for income
- Illegal gold mining
- Migrating to scarcely populated areas
- Marijuana growing for smoking
- Strengthening of ambulance group

Appendix 2: Adaptation and coping strategies along the Kenyan Coastline

Hazard	Impact	Coping strategy
Drought	Reduced agricultural output	Rely of relief aid; credit from local shops
	Low fish catch	Turn to subsistence agriculture
	Reduced grazing pasture and water for livestock	Move in search for pasture and water; sell livestock
	Illness within the community	Seek medical attention; use of traditional cures
	Household food insecurity	Rely of relief aid; credit from local shops
Extreme heat	Increased cases of sudden death	Seek medical attention
	Reduced fish catch	Turn to subsistence farming
	Poor/No agricultural output	Rely on food aid; make do the best they can
	Water shortage	Trek long distances in search of water; govt. aid
	Reduced availability of manual labour	Make do with the best with the labour available
Strong winds	Reduced fish catch	Inshore fishing; turn to subsistence agriculture
	Illness affecting livestock	Zero grazing; sell livestock
	Up-rooting of trees	Re-plant trees; assistance from government
	Damage to dwellings	Re-build structure; move in with relatives
Turbulent sea	Capsizing of fishing vessels	Seek opportunity to team up with other fishermen; spend time repairing nets
	Loss of fishing equipment	Search for funds to purchase gear; subsistence agric.
	Reduced fish catch	Fish inshore; seek land-based livelihoods

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