Climate Change in African Drylands: Adaptive Livelihood Options [1]

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In the drylands[1] of Sub Saharan Africa (SSA), land degradation exacerbated by human activity, including certain traditional coping strategies are already having a negative effect on overall food security (UNSO 2002). Land degradation in drylands will likely be more dramatic under a scenario of climate change, due to projected increases in evapo-transpirative demand, increased spatial and temporal variability of rainfall, and greater rainfall intensity.

Food security is not a simple measure of the amount of food people can produce for themselves; but rather a complex system including environment market access, and income stability, amongst other factors. Household level food security is a function of what activities makes up a livelihood; each household will have separate challenges to maintaining food security in light of climate change. Adaptation measures are needed in order to maintain household food security in the face of the threat of desertification[2] exacerbated by climate change.

This paper seeks to highlight food security challenges facing the drylands in SSA, taking in to account projected impacts of climate change and ongoing land degradation on the three most prevalent dryland agro-ecological zones, namely arid, semi arid, and sub-humid. Furthermore, this paper will discuss various potential practical adaptation measures *via* three different types of climate change adaptation opportunities; namely natural resource management, market, and institutional options which could be considered for each agro-ecological zone in order to help anticipate and respond to potential climate change exacerbated desertification.

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1. Introduction - Land Degradation in the Drylands of Africa

Home to over 2 billion people living in some 100 countries, drylands cover more than 40% of the earth's surface. In Africa, some 43% of land is estimated to fall within the drylands, where approximately 325 million people reside and these numbers are growing faster than the global average (UNSO 2002). While not as arid as deserts, drylands are characterized by low and erratic precipitation, high temperatures and high rates of evapo-transpiration.

[1] For the purpose of this paper, the term **drylands** refer to all terrestrial regions where the production of crops, forage, wood and other ecosystem services are limited by water (millennium Ecosystem Assessment, 2005), which encompass all lands where the climate is classified as dry sub-humid, semi-arid and arid, exclusive of hyper-arid areas.

[2] The term *desertification* in this paper is defined as land degradation in drylands, leading to a condition of significantly reduced fertility and water holding capacity. Desertification is a reversible condition of the earth surface, as opposed to aridity, which is a climatic condition.

Human activities and traditional coping strategies such as including overgrazing, over cropping, poorly managed mechanized farming and poor irrigation, illegal and excessive logging and burning bush lands and forests are largely responsible for the current desertification outcomes. In spite of their environmental sensitivity and perceived fragility, and despite the prevailing negative perceptions of drylands in terms of economic and livelihood potentials, these ecosystems have supported human populations for centuries. Today some of the world's fastest growing urban centers are located in these regions, such as Cairo, Cape Town, and Kano. Many rural dryland dwellers make their living through the production of livestock and rain-fed/irrigated agricultural crops. Drylands also provide a habitat for a variety of plant and animal species, and wildlife-based tourism generates significant income for national economies. Furthermore, semi-arid woodlands are an important source of biomass for fuel and construction.

Inhabitants of drylands in SSA have learned, over millennia, to cope with variable inter and intra seasonal rainfall and the risks of weather-related shocks. However, as a result of high poverty rates, changing socio-economic and political circumstances and demographic growth, traditional coping strategies are becoming insufficient. In the recent past, some 25% - or 320 million hectares - of the already fragile resource base in African drylands have been further degraded, often referred to as 'desertification', by unsustainable land uses, such as over-grazing, over-cultivation, illegal and excessive fuel wood collection and poor irrigation practices, often compounded by poorly conceived policies and ineffective governance (UNEP 2006).

This paper seeks to highlight the food security challenges facing the drylands in SSA in light of projected impacts of climate change and ongoing land degradation on three dryland agro-ecological zones, namely arid, semi arid, and sub-humid. Further, this paper will also discuss various practical adaptation measures, in terms of three categories of climate change adaptation opportunities; namely natural resource management based opportunities, market based opportunities, and institutional climate related opportunities that should be considered for each agro-ecological zone in order to help manage climate change and reverse land degradation in drylands.

2. Conceptualization of Climate Change and related concepts

Terminologies used to define climate change and related concepts often vary from one practitioner to the other and interpretations also vary over time. The term 'climate change' is often used to include the occurrence of medium term changes in weather patterns, increased climate variability and more frequent climatic extremes (i.e. droughts and floods). However, distinctions should be made between these concepts for the sake of analytical clarity and in terms of management implications.

Table 1: Conceptualization of Climate Change and related concepts

Climate Change	The Intergovernmental Panel on Climate Change (IPCC), an authoritative voice on climate change issues, refers to climate change as *any change in climate over time, whether due to natural variability or as a result of human activity* (IPCC,2007). The United Nations Framework Convention on Climate Change (UNFCCC) Article 1, however, makes a distinction between climate change attributable to human activities altering the atmospheric composition, and *climate variability* attributable to natural causes.
Land Degradation and Desertification	The United Nations Convention to Combat Desertification (UNCCD) defines desertification as land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities. Desertification does not refer to hyper-arid regions like deserts, but to less arid regions that can and do support an abundance of life, agriculture, livestock, communities, economies, and cultures. The soils in parts of these regions are becoming so degraded that they can no longer support life (UNCCD 2009).

Table 1: Conceptualization of Climate Change and related concepts	
Adaptation	Put simplistically, whereas 'mitigation' refers to tackling the anthropogenic causes of climate changes, 'adaptation' focuses on reducing negative effects of climate change by modifying systems to take into account new/anticipated climatic conditions. IPPC defines *adaptive capacity* as the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. *Adaptive coping mechanisms* Strategies that have evolved over time through peoples' lengthy experience in dealing with the known and understood natural variation that they expect in terms of seasons, combined with their specific responses to a season as it unfolds *Adaptive strategies* Longer-term (beyond a single season) strategies that are needed for people to respond to a new set of evolving conditions (biophysical, social and economic) which they have not previously experienced. The extent to which communities are able to successfully respond to a new set of circumstances will depend upon their adaptive capacity.
Mitigation	Mitigation refers to elimination or reduction of frequency, magnitude, or severity of exposure to environmental, economic, legal, or social risks, or minimization of the potential impact of a threat or warning. Climate change mitigation measures recognize that the amount of greenhouse gases in the atmosphere will influence the rate and magnitude of climate change. Therefore it is within the capacity of humans to influence their exposure to change. Climate change mitigation measures include energy conservation measures, implementing land use plans, strengthening institutional and legislative mechanisms, energy efficiency measures, waste management, substituting fossil fuels with renewable energy sources and measures in the transport and agricultural sectors, as well as sequestering carbon biologically through reforestation or geo-physically (inside the earth's core). These activities contribute to reducing disaster risk by reducing expected climate change impacts (IATF/DR 2006).

3. Determinants of Food Security in Sub Saharan Africa

Food security occurs when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preference for an active and healthy life (FAO 2002). Household level food security is rather complex, trans-boundary and multifaceted including biophysical, socio-economic, political, demographic, gender and other dimensions. In general, the level of food insecurity is measured by three key indicators, namely: availability, access, and utilization. According to the African Commission's Food Security Report (2005), 27% of the total population in Africa is undernourished; nearly half of the children of Africa suffer from stunting; and acute malnutrition (more than 10%) is observed in more than 15 countries. Africa currently seeks to cover its food insecurity by imports valued at some US$20 billion annually, in addition to seeking food aid (AUC and NEPAD, 2006).

Food ***availability*** is derived from domestic agricultural output and net food imports at the national level. Food ***access*** depends largely on household purchasing power, which varies in relation to market integration, price policies and temporal market conditions. Food ***utilization*** is determined by food safety and quality, how much a person eats and how well a person converts food to energy, all of which affect proper biological use of food, nutritional status and growth. Adequate food utilization requires a diet providing sufficient energy and essential nutrients, potable water, adequate sanitation, access to health services and proper feeding practices and illness management. For the purpose of this paper, food security will be determined by the availability of food, access to, and the utilization of the food.

Understanding that a household's food security is affected by outside factors beyond their control is an important point as we begin to look at food security as a multidimensional system. Food security is influenced by various factors, including in neighboring and distant countries, and will become more difficult with the threat of climate change and potential interrelated land degradation. Household food security will be a function of what makes up livelihoods and each household will have separate challenges to maintaining food security in light of climate change and desertification. The direct effects of climate change and land degradation on food security will be discussed later in this paper.

4. Impacts and Implications of Climate Change and Land Degradation on Sub-Saharan Africa

The Fourth African Assessment Report on climate change released by IPCC highlights major issues related to potential impacts as a result of climate change (IPCC 2007). It indicates that Africa is one of the most vulnerable continents to climate change and climate variability. This is a result of the interaction of 'multiple stresses' including land degradation and desertification, declining run-off from water catchments, high dependence on subsistence agriculture, HIV/AIDS prevalence, inadequate government mechanisms and rapid population growth occurring at various levels, and low adaptive capacity due to factors such as extreme poverty, frequent natural disasters i.e. droughts and floods, and rainfall-dependent agriculture (Boko *et al* 2007).

The likely impacts of climate change will add to these existing stresses and exacerbate the effects of land degradation. Increased temperatures levels are expected to cause additional loss of moisture from the soil, reduced and more intense rainfall and higher frequency and severity of extreme climatic events, such as floods and droughts. These factors are already leading to a loss of biological and economic productivity and putting drylands population at risk of short- and long-term food insecurity.

There is considerable variability and uncertainty in climate change projections. Nevertheless, there is a reasonable agreement from a suite of different models that Africa is one of the most vulnerable continents to climate change and variability. The IPCC 4th African Assessment Report estimates that by 2020 between 75 and 250 million people are likely to be exposed to increased water stress and that rain fed agricultural yields could be reduced by up to 50% in Africa if production practices remain unchanged.

Drought-prone areas *inter alia* are particularly deemed to suffer complex, localized impacts of climate variability/change. In the Sahel, for instance, changes in temperature and rainfall patterns have reduced the length of the vegetative period and make it difficult to continue the cultivation of traditional varieties of long and short cycle millets (Rosenzweig et al. 2007). Given the social, legislative, market and weather-based sources of vulnerability already prevailing in the region, reduction in agricultural productivity and land area suitable for agriculture, even if slight, would cause disproportionately large detrimental effects (IPCC 2007, Dietz *et al* 2004).

The most vulnerable communities to the impacts of climate change inhabit the dryland areas. For instance, the pastoralists inhabiting drylands have been able to survive the harsh environments of the drylands by practicing various sustainable livelihood approaches including seasonal movements, keeping livestock among others. However, with the threats of changes in climate, exacerbating current trends of encroachment on grazing lands by agriculturists and other factors they may be forced to consider other livelihood options, including permanent migration, in order to cope with cumulative changes.

5. The Impact of Climate Change and Land Degradation on the Food Security of specific Agro-ecological Zones

The impacts of climate change and desertification on household food security will vary throughout SSA. While the drylands are predominantly inhabited by pastoralist and agro-pastoralists, the livelihood makeup for each group varies from place to place, and includes the sub-humid zone which is inhabited by agriculturists. For the purpose of this paper, three agro-ecologic zones will be used in order to examine differential food security and adaptive measures that could be taken in the face of climate change and potential resultant desertification on respective dominant livelihoods and social vulnerabilities. Each zone offers distinct opportunities for livelihood sustenance and development, reflecting different agro-ecological conditions.

Table 2: Drylands livelihood challenges by agro ecological zone

	Arid	Semi-arid	Dry sub-humid
Livelihood challenges	Changes in rainfall patterns and growing pressure on land and associated land degradation have been adding to stress on the already vulnerable livelihoods of pastoralist societies. Increased aridity, climatic variability and hazards such as prolonged droughts often induce malnutrition and/or disease of livestock due to unavailability of sufficient fodder and deterioration in pastoral lands, which lead to reduced willingness of traders to purchase animals in poor conditions. Fluctuating market prices of livestock products and feed as well as overall shortage of commodities in turn affect pastoralists' food security markedly due to their high dependence on market exchange for acquiring staple foods. Competition and conflicts between pastoral communities and with other groups over scarce and scattered resources are also on the rise.	Conversion of rangelands to cultivated lands in areas that do not have an adequate level of provisioning and supporting services, notably water and soil fertility, and inadequate dryland irrigation and cultivation practices, has resulted in severe soil salinization and erosion (MEA, 2005). Climate change could further reduce water availability in the semi-arid ecosystem and in turn spur the spread of land degradation and reduction of primary production. Conflict already occurs between herdsmen and farmers in semi-arid regions (IPCC, 2001).	Climate induced uncertainty associated with inter and intra seasonal rainfall variability remains a fundamental constraint to agricultural production. While empirical data are still limited, potential impacts of climate change are likely to make the situation worse with decreased rain, reduced soil moisture due to higher evapo-transpiration rates and increased heat stress associated with higher temperatures, on crops, pest, disease and weeds. These changes in scale effect – both in terms of time and space – will result in diminished yields and higher overall volatility, which trickles down to all aspects of food security chain from consumers, land owners, and all the way to landless farmers who make a livelihood on other peoples' farms.

Arid

The arid zone is characterized by low moisture availability and lack of vegetation cover owing to a combination of low annual rainfall (200 - 500 millimeters for the purpose of this paper), high potential evapo-transpiration rates and often shallow, saline and calcareous soil. With limited supplies of permanent pastures and water, nomadic and transhumant pastoral systems based on communal grazing are the dominant farming systems. Arid regions moisture conditions are inadequate to support abundant vegetative cover of the land surface. The inhabitants of the arid zone, for that reason, are either pastoralists or oasis dwellers who are dependent on trade of livestock and market access to purchase food stuffs. Pastoralists do not eat their own herd under normal situations, making markets for the sale of their animals or of animal products key to their livelihoods. There is also irrigated agriculture in some arid areas along perennial or ephemeral water courses such as the Nile. Groundwater extraction on a large scale occurs in arid (and hyper arid) areas in parts of North Africa.

Pastoralism in Africa evolved in response to long-term climate variability, and is by its very nature a form of adaptation to climate change. The Sahara entered a period of prolonged desiccation approximately 7000 years ago. With no reliable supplies of permanent water, pastoralism enabled people to adapt to an increasingly arid and unpredictable environment by moving livestock according to the shifting availability of water and pasture (Brooks 2006).

Although in a few East African pastoral groups, including for example the Maasai and the Turkana, milk from the household's own cattle was until recently the source of between half and two-thirds of calorie intake, and meat and blood for perhaps another 10 per cent, in most pastoral livelihood systems milk is responsible for between a third and a half of calorie intake (Swift et al 1990). When a market for their animals is not present or access is blocked, pastoralists' overall food security is therefore at risk.

Dependence on the market for a substantial part of the daily calorific intake makes pastoralists vulnerable to changing prices of the products they sell (live animals, milk, animal products like hides, skins and wool) and the cereals they buy (Swift 1998). Cereal prices change in response to such supply-side factors such as the success of the harvest, remaining farmer and trader stocks and prospects for the current cropping season; and demand-side factors which include urban and pastoral needs, and livestock prices; which change in turn according to such supply-side factors as the success of the breeding season, alternative sources of pastoral nutrition, herd-owners' expectation about pasture availability in the forthcoming dry season, and demand-side factors such as seasonal live weight and condition of the animals, and cash income of purchasers such as farmers and urban people (Swift 1989). These pastoral terms of trade are volatile and will only get more volatile with the threat of increased climate change and desertification.

In addition to obvious economic concerns, various other factors including health of animal stocks, amount of rainfall received and overall environment play a large role in the success or failure of their livelihood activities and overall quality of life.

Semi arid

The semi arid zone receives 500-1,000 millimeters of rainfall annually and has a growing period of 3 to 6 months. Rain may come over two periods (bi-model distribution) effectively reducing the useable amount. This zone is typically agro-pastoralists who make their livelihoods out of drought-tolerant crops production and livestock rearing. Due to the typically poor soils deficient in nitrogen and phosphorus and limited precipitation, crop production is mainly for subsistence purposes, except some cash crops, with few resources devoted to livestock production. While agro-pastoralists still rely on markets for cereals and other products not produced domestically, they have greater flexibility in the sale of livestock compared with occupants of an arid zone.

An agro-pastoral system produces a substantial part of the cereals they require for their food security. They are dependent on markets for purchase of cereals and other products that they do not produce themselves, but their dependence on the market is not to the extent as the strict pastoralist. The fact that they both cultivate and maintain herds allows for more flexibility in the sale of their livestock. Given the poor soils and limited precipitation in this zone, crop production (apart from cash crops such as groundnut, cowpea, and cotton) is undertaken for subsistence only, with few resources devoted to livestock production, except in areas with good access to markets. To realize the potential of this zone, especially in areas with good market access, investments should focus on extension, education, and credit in livestock fattening programs, milk production, and improved marketing and health facilities.

In common with the pastoralist communities in the arid zone, the health of their animals, the amount of rain they receive, and the overall environment also play vital roles on the success of the livelihood systems and overall food security. With climate change, rainfall is expected to become more variable

and introduction of new livestock diseases may occur. The agricultural aspect of their livelihood will be challenged in a similar way as for the population of the sub humid zone.

Sub humid

The sub humid zone consists of savannah type vegetation which receives between 1,000 and 1,500 millimeters of rainfall annually with a growing period of 6 to 9 months. While mixed crop-livestock farming is partly practiced, the predominant livelihood is subsistence and smallholder agriculture, largely rain-fed. A wide array of food and forage crops are grown including maize, millet, sorghum, cassava, yam, groundnut, cowpeas and leguminous forages.

The predominant livelihood for the inhabitants of the sub humid zone is agriculture. While pastoral and agro-pastoral livelihoods are based in some part by the herding and breeding of animals, agriculture communities are fully dependent on the environment for the production of the majority of the food they consume. While they do go to market with crops, they are not as dependent of favorable markets as the pastoral or agro-pastoralists.

With increased climate change, the amount of rain and soil moisture available will most likely decrease. Heat stress on crops and increased pest, disease and weeds will also be prevalent. These changes will result in reduced yields and increased overall volatility. In simple terms, the amount of food that is able to be produced will decrease. This effect will trickle down to all aspects of food security from the producer to the worker who makes his/her livelihood on other peoples' farms. Taking climate change out of the equation, enough food could be produced to feed the population. With the growing threat of climate change and desertification, steps need to be taken in order to ensure enough food is being produced, and food security is maintained. Furthermore, the change in scale effect – time and space- means that techniques which had worked in the past may no longer work and/or may need to be modified. This will require the combined efforts of affected communities, government and diverse development partners.

6. The Impacts of Climate Change and Land Degradation on Pastoral Livelihoods

Pastoral households are those in which at least 50% of household gross revenue (including income and consumption) comes from livestock or livestock-related activities (Swift 1998). Pastoral societies of Africa inhabit drylands environments which exhibit wide variations in rainfall amounts from year to year. Droughts are recurrent hazards, as are outbreaks of diseases which affect livestock. These populations are confronted by extreme variability in the production environment. Survival in such areas therefore depends upon the ability of societies to adapt to strategies which mitigate the effects of recurrent drought and permit the long-term occupation of Africa's rangelands (Campbell, 1977).

Pastoralism is a finely-honed symbiotic relationship between local ecology, domesticated livestock and people in resource-scarce, climatically marginal and highly variable conditions. It represents a complex form of natural resource management, involving a continuous ecological balance between pastures, livestock and people (WISP 2007). When the fine balance is upset, as it is with climate change and range desertification, the effects on the pastoral way of life can be dramatic.

For pastoralists and agro-pastoralists, whose livelihoods and food security depending on livestock, drought conditions cause malnutrition or disease of livestock due to unavailability of sufficient fodder and deterioration in pastoral lands. The impacts on local markets cause a hike in the prices of feed and a significant drop in the prices of livestock. [See **Appendix 2: "Normal" pastoral adaptive coping livelihood strategies.**]

The threat of climate change and desertification, however, has brought - and will continue to bring- increased land degradation to the already marginal lands inhabited by pastoralists. This degradation of already fringe lands onto which they have typically been displaced over the last century will exacerbate the negative impacts of climate change and desertification to drylands communities and increase communities' overall social vulnerability and livelihoods. Climate change is already having a devastating impact on the lives of the pastoral communities. Increased climate change will threaten the well-being of human populations and related economic situations. This vulnerability also includes the relative potential for physical harm and social disruption to subpopulations of societies and their larger subsystems (as defined by their on socioeconomic status, age, gender, race and ethnicity, family structure, residential location and other demographic variables).

As what is considered 'normal' changes due to the increasing effects of climate change and desertification, many pastoralist coping strategies will no doubt change, as many strategies will no longer be viable. Shocks will force pastoralist to change the system they have been using for centuries and adapt in different ways. Desertification and climate change will directly degrade the land resources that the pastoralists depend on, making maintaining livelihoods an even bigger challenge. Indeed, the effect of climate change and desertification will be felt on all levels, including physical harm and social disruption to subpopulations of societies and their larger subsystems.

Table 3: Anticipated Impacts of increased land degradation and climate change on agro ecological specific livelihoods	
Arid agro ecological zone	Because of their dependence on markets for food, pastoralists' food security is affected by fluctuating market prices for commodities and overall shortages. What happens to agriculture products around the world will have a direct effect on the population in arid zones. Furthermore, substantial economic dependence on livestock has important consequences for food security. On the positive side, this gives households flexibility. On the negative side, however, it can create new sorts of vulnerabilities for pastoral households. Two of the most important are the timing of seasonal economic and nutritional stresses, and the increased dependence of market exchange for acquiring staple foods. Dependence on the market for a substantial part of the daily calorie intake makes pastoralists vulnerable to changing prices of the products they sell (live animals, milk, animal products like hides, skins and wool) and the cereals they buy (Swift 1998). Cereal prices change in response to such supply-side factors such as the success of the harvest, remaining farmer and trader stocks, prospects for the current cropping season; and demand-side factors which include urban and pastoral needs, and livestock prices; which change in turn according to such supply-side factors as the success of the breeding season, alternative sources of pastoral nutrition, herd-owners' expectation about pasture availability in the forthcoming dry season, and demand-side factors such as seasonal live weight and condition of the animals, and cash income of purchasers such as farmers and urban people (Swift 1989). These pastoral terms of trade are volatile and will only get more volatile with the threat of increased climate change and desertification. Indeed, one need only to look at the pastoral term of trade during a drought to see what effects climate change and desertification will likely have on the livelihoods of these pastoral communities.
Semi-Arid agro ecological zone	Similar to the pastoralist communities in the arid zone, the health of their animals, the amount of rain they receive, and the overall environment also play vital roles on the success of the livelihood systems and overall food security. With increased climate change, rainfall will become more variable and introduction of new livestock diseases may occur. The agriculture aspect of their livelihood will be challenged in ways similar to the population of the sub humid zone.
Dry sub-humid agro ecological zone	With increased climate change, the amount of effective rainfall [soil moisture] that will be available will likely decrease. Heat stress on crops; increased pest, disease and weeds may also be prevalent. Such changes would result in reduced yields and increased overall volatility. In simple terms, the amount of food that is able to be produced will decrease *ceteris paribus*. This effect will trickle down to all aspects of food security from the producer to farm labourers. Taking climate change out of the equation, enough food could be produced to feed the population. With the growing threat of climate change and desertification, steps need to be taken in order to ensure enough food is being produced, and food security is maintained. Furthermore, the change in scale effect – time and space- means that techniques which had worked in the past may no longer work and/or may need to be modified. This will require the combined efforts of affected communities, government and diverse development partners.

7. Adaptation Opportunities for Different Dryland Agro-ecological Zones in SSA

Despite the overall sense of despair and concern for the future of SSA, all hope is not lost in efforts to adapt to climate change and desertification in Sub Saharan Arica. There are many adaptation techniques that can be used to limit the effects of climate change and desertification on livelihoods. Many of these techniques are the very same techniques that have been used for generations in order to react to shocks such as floods or drought, and can be used in light of the increasing threat of climate change and desertification. While there is hope, a sense of urgency is needed in order to prepare and adapt to the looming threat.

How can the ultimate impacts of land degradation be better abated and controlled, and food security and sustainable livelihoods be ensured in SSA drylands in the face of climate change? The answer lies not only in climatic elements but also in the adaptative as well as mitigative capacities of affected populations and on the nature and extent of the measures adopted. Drylands communities in SSA already have a long record of spontaneous adaptation to climate variability; yet more intensive and extensive adaptation exercises than is currently occurring are required, including the supporting policies, especially since it is estimated that, by the 2080s, the proportion of arid and semi-arid lands in Africa is likely to increase by 5-8% (IPCC 2007).

While the drylands in SSA are predominantly inhabited by pastoralist and agro-pastoralists, agro-ecological settings are marked by a variety of livelihood orientations, reflected as different combinations of food security/livelihood challenges and conceivable climate adaptation responses. The adaptation options presented thus convey a sense of the spectrum of opportunities rather than an exhaustive list. Centralized interventions that fail to recognize such spatial heterogeneity of drylands and location-specific interaction of socioeconomic and biophysical processes may limit the effectiveness of a particular adaptation option.

It is also important to note that many of the proposed and piloted adaptation measures are applicable across the agro-ecological zones, with different degree of required intensity, offering opportunities for learning and replications among locations. In response to the current wave of decentralization in Africa, for instance, local knowledge sharing and networking efforts have been increasingly promoted. In Benin, for example co-operation among farmers, researchers, community leaders and meteorologists has improved farmers' access to climate-related information and provided new opportunities to share and up-scale good farming techniques and practices (IDRC and DFID 2007-08). Such initiatives have been proven to be a powerful mechanism not only to catalyze change at a scale which would not otherwise be possible, but also to strengthen community cohesiveness and protect traditional indigenous knowledge for responding to climate viability.

Similarly, existing land tenure arrangements and ecosystem services have come under increased strain in many SSA counties, given the continued scarcity of natural resources coupled with growing demographic pressure, fuelling conflicts among dryland communities (Anderson 2008). The imperative at the policy level, therefore, is to improve dryland dwellers' property and access rights to a variety of pastures and water resources.

With each agro-ecological zone, three categories of different adaptation measures will be utilized in order to give a clearer picture of the possibilities in the drylands of Africa. The three categories that will be used are (a) natural resource management based adaptation opportunities, (b) market based opportunities, and (c) institutional based opportunities. For the purpose of this discussion, these categories will be defined as:

Table 4: Definitions of categorical adaptation measures

Natural resource management (NRM) based opportunities	Opportunities that focus on management of natural resources such as land, water, soil, plants and animals, with a particular focus on how management affects the quality of life for both present and future generations. This discipline has given rise to the notion of sustainable development, a principle which forms the basis for land management and environmental governance.
Market based opportunities	Opportunities that result in increased income *via* a multitude of economic opportunities including livestock, market access, and eco-tourism to name a few.
Institutional based opportunities	Opportunities that focus on local level structural change such as extension/education, micro-credit and migration.

The following recommendations are by no means a comprehensive list of all possible climate change adaptation measures; but rather a sample of some measures that can be taken in each specific agro-ecological zone to limit the negative effects climate change and desertification will have on livelihoods and overall food security. For the sake of brevity only certain adaptation methods have been expounded upon for each agro-ecological zone in the body of the paper. [See **Appendix 3: Livelihoods/Food Security Challenges and Possible Adaptation Measure by Dryland Agro-ecological Zone** for a table of adaptation opportunities.]

Arid Zone Adaptation Measures

There are many possible adaptation options for the arid zone that will both help maintain livelihoods as well as help push the communities forward with new techniques and land management tools. Many people will remain pastoralists, and for whom, therefore, improving property rights to a variety of pastures and water resources and the right to move between those resources will be important. This step can improve the use of the sparse water resources and pastures that are dominated by annual grass species. Scarcer resources, coupled with current levels of demographic growth, are likely to lead to stronger competition between pastoral communities and between these and other groups possibly resulting in conflict and even violent clashes (Anderson 2008).

The following are some recommendations for climate change adaptation activities which should be considered in the arid zone:

Natural Resource Based Opportunities

Herd management: Several herd management techniques that should be considered including herd diversity, maintenance of female-dominated herds, herd size, and herd splitting (Oxfam 2008):

Herd diversity – Pastoralists manage both grazing and browsing livestock species to optimize different range resources and ensure the conservation of rangeland ecosystems. For example, many East African pastoralists stock their herd with a mixture of cattle, camels, goats, and sheep.

Maintenance of female-dominated herds – A female-dominated herd structure is used to offset long calving intervals and thus stabilize milk production.

Herd size – Building up the herd size in recovery periods between droughts protects against total loss of the herd during drought.

Herd splitting – Splitting the herd into smaller groups and moving them to different areas is used to prevent over-grazing and maintain the long-term productivity of the range.

Home Gardens: Domestic rainwater harvesting may also allow for communities to maintain small home gardens, that will allow them to not only diversify there diets as well as livelihoods. Home gardens are by no means a new technology, but one that can add to the diversity of diets and livelihoods in the drylands if they are utilized in a sustainable way.

Rain-water harvesting: When climate changes, water movements change and human technology adapts. Rainwater harvesting (RWH) is broadly defined as the collection and concentration of runoff for productive purposes. It includes all methods of concentrating, diverting, collecting, storing, utilizing and managing runoff for productive uses. This provides water that can be used for domestic, livestock and irrigation or commercial purposes. Rainwater harvesting is one adaptation measure that does not require large capital investment, it is essentially a management approach, to provide water resources at the community level an ensure livelihoods are maintained (IRIN 2006).

Marked Based Opportunities

Drought resistant/tolerant breeds: The introduction of drought resistant/tolerant breeds of livestock is essential for the continued success of pastoralism in the region. With increased risks resulting from climate change, herds will have to be more resilient in order to cope with stresses resulting from weather and water variability.

Diversification of livelihoods: Diversification of pastoral livelihoods is important given the stresses on pastoral communities and the growth in population. The need to diversify livelihood activities should also include non pastoral cash generation activities such as small businesses. Pastoralists need to further diversify their livelihoods, both within the pastoral system (i.e. increasing reliance on more drought-resistant species such as camels) and outside of the livestock production sector.

Exchange of livestock for agriculture commodities: Exchange of livestock for agriculture commodities, and *vise versa* could be considered as a potential adaptation opportunity. This exchange that happens normally throughout the drylands introduces another method for commodity exchange other than reliance on markets which may often be inaccessible to many pastoral communities.

Livestock feed supplementation and fattening: The practice of supplementation of livestock grazing with other feeds is common during periods of shocks such as droughts, and therefore should be considered as a climate change adaptation measure. Improved fodder species to increase livestock strength and milk production are being looked in to, which would improve productivity and therefore resilience of both livestock and pastoralists in the event of increased floods and droughts via climate change (Oxfam 2008).

Livestock products value addition: The creation of value added products from livestock such as hides and skins is a method that could be used to diversify livelihoods and income generation.

Management of livestock diseases: Both human and livestock diseases can increase during periods of stress, particularly floods and drought. Preventative measures include avoidance of areas known to be particularly susceptible to disease and migration. Education on disease management methods as well as increased veterinary assistance should be considered in order to help pastoralist maintain the basis of their livelihood system.

Institutional Based Opportunities

Conflict resolution and security reinforcement: Better policies and planning needs to be implemented in order to avoid conflict and security threats as population pressure and land concentration begins to push people to migrate to different regions. In addition to conflicts over land, migration is likely to bring inappropriate technology and land management issues that will only exacerbate an already stressful and volatile situation.

Extension and education: Extension and education needs to be utilized in order to share knowledge and information regarding weather as well as soil conservation and water management methods.

Migration: Over time, pastoral groups will shift out of drier areas that are no longer viable to zones that are more humid and have more predictable rainfall patterns. In this case existing land tenure arrangements and services in these areas will come under increased strain, exacerbating relations between communities and fuelling conflict (Anderson 2008). The movement of some people out of pastoralism and into other livelihoods should in some cases be considered, but as a last option. As much as pastoralism is in itself a viable economic activity, there is also a need to find ways of alleviating the growing population pressure on the land, as well as increasing the range of cash sources available to pastoralist families, many of whom currently rely on remittances sent from family members working elsewhere. There are already thousands of destitute ex-pastoralists who will need special support and attention to enable them to enter other livelihoods, through accessing their right to education, health care, and other services.

Pastoral passport: The idea of a pastoral passport could be looked in to as an opportunity for pastoral communities that need to cross borders for grazing. For example, the Economic Community of West African States (ECOWAS) has created a system whereby pastoralists from one nation can now easily cross the border of another nation for grazing purposes without experiencing legal problems. In the ECOWAS system pastoralists have received a 'livestock passport', 'international transhumance certificate,' and a 'handbook of travel.' This promotes mobility, an essential attribute of pastoral societies (GL-CRSP 2004).

Semi-Arid Zone Adaptation Measures

In the semi-arid zone land and water degradation, overgrazing and slash and burn practices have led to food shortages and to significant environmental degradation. According to most experts, a sound and comprehensive approach based on the conservation of water and soil fertility for a balanced and sustained agricultural production system is a basis for improved food security in the sub-region. Semi-arid conditions make agriculture challenging, and climate change will likely to reduce the length of growing season as well as force large regions of marginal agriculture out of production. Some agricultural systems are vulnerable to projected impacts of climate change, including maize and sorghum-based systems that are reliant on rainfed agriculture.

Rural farmers have been employing coping strategies and tactics, especially in places where droughts recur, and have developed their own ways of assessing the prospects for favorable household or village seasonal food production. Home gardens and sheep fattening have contributed greatly to improving the adaptive capacity of small rural farmers in Kordofan and Darfur states of Western Sudan (Osman et al 2006). In many locations food crops have replaced cash crops, and more resilient crop varieties have been introduced. Tribal and individual movements and migration are identified as adaptation options, e.g. in Western Africa since they provide for employment and income diversification away from their farms and reduce their vulnerability to drought (Osman et al 2006).

The following are some recommendations for climate change adaptation activities that should be considered in the semi-arid zone where pastoralism is mixed with agriculture activities. Many of the adaptation measures are similar to that of the arid zone as agro-pastoralists maintain similar livelihoods:

Natural Resource Based Opportunities

Cropping pattern adjustments: Crops can be planted farther apart so that more moisture is available for each row, increasing the likelihood that they will survive a period of drought. Maize varieties that mature faster have been brought in, again limiting the threat of dry spells.

Improved tree management and planting: In Senegal and Burkina Faso, local land users have improved their adaptive capacity by using traditional pruning and fertilizing techniques to double tree densities in semi-arid areas. These techniques help in holding soils together and reversing desertification processes. Although tree planning is not a new phenomenon, it is being undertaken in some arid areas in a much more comprehensive way. Afforestation techniques shown in the box below are important in increasing land cover as well as trapping moisture in the soil. With increased evapo - transpiration, various patterns of tree planting is an important adaptive method that should be introduced.

Box 1: West Africa: Afforestation through vegetative propagation; Growing *acacia albida* in Burkina Faso

The genus Acacia comprises many species which are important for firewood, fodder, tannin, pulpwood, shelterbelts, and soil improvement. Species of Acacia are dispersed widely in tropical and subtropical regions of Australia, South America, Asia, and Africa. They are often regarded as being quick growing but short lived, i.e. most live from 12 to 15 years in suitable conditions but many will last much longer. Virtually all Acacias are propagated from seed. This is a reliable method which, with most commonly grown species, presents few problems. In the past, the majority of forest trees have been propagated through the traditional family forestry method, where trees are grown from seeds and propagated sexually.

In the last few years a number of species have been successfully propagated from cuttings and this trend can be expected to increase. Best results are achieved with cuttings of about 7.5-10 c in length of mature, current season's growth with the foliage removed from the lower two-thirds of the stem. In Burkina Faso, for several decades Mossi farmers from Passoré have been using a natural reproduction method for the Acacia albida tree. The farmers succeeded in getting the plot "colonized" by Acacia albida trees by cutting the plants roots so that they will propagate. These root-suckers grow and become adult trees within seven years. Then, the farmers cut the lateral roots of those trees and other root-suckers appear and the process is continued

Source: UNFCCC Database on Local Coping Strategies http://maindb.unfccc.int/public/adaptation

Soil and water conservation: Soil and water conservation should be stressed as a way of maintaining viable crop production for fodder and food. There are always strong links between measures for soil conservation and measures for water conservation, and this applies equally in semi-arid areas. Many measures are directed primarily to one or the other, but most contain an element of both. Reduction of surface run-off by structures or by changes in land management will also help to reduce erosion. Similarly, reducing erosion will usually involve preventing splash erosion, or formation of crusts, or breakdown of structure, all of which will increase infiltration, and so help the water conservation (FAO 1987). The subsistence farmer cannot afford to respond to philosophical or emotional appeals to care for the soil, and this means that conservation measures must have visible short-term benefits to the farmer. For the subsistence farmer the benefit he would most appreciate might be increased yields per unit of land or better production per unit of labor.

Marked Based Opportunities

Diversification of livelihoods: Diversification of agro-pastoral livelihoods is important given the stresses on pastoral communities and the growth in population. The need to diversify livelihood activities should also include non pastoral and agricultural cash generation activities such as small businesses. Agro-pastoralists need to further diversify their livelihoods, both within the pastoral system (i.e. increasing reliance on more drought-resistant species such as camels), out of livestock production, as well as finding new and innovative ways to make a living.

Drought tolerant crop varieties: Most climate models project that global warming will make arable land in many developing countries less productive or unusable. Advocates of genetically modified (GM) crops often defend the technology by arguing that drought and salt-tolerant varieties can play an important role in adapting to global warming (Randerson 2008). There is therefore need to introduce alternative crop varieties in the drylands areas that are drought-resistant. Projected reductions in yield in some countries could be as much as 50% by 2020 (IPCC 2007).

Research on drought tolerant crops is already being conducted at research such as those which are part of the Consultative Group on International Agriculture Research (CGIAR)[3] system that will allow for continued agriculture production in light of loss of moisture due to increased evapo-transpiration via climate change and desertification. While there are many opponents of GM crops, the benefit of such technology would hard to dismiss in light of prospective climate change and trends of desertification in areas of Sub Saharan Africa.

For example, the researchers at CIMMYT are optimistic offering promising ways to deal with the challenges of drought. Several approaches have been investigated, such as:

- Developing plants that stall seed development during periods of drought in order to conserve water, or that are better at taking up water (known as drought avoidance)
- Over expression of a gene related to drought tolerance
- Accumulation of sugars and salts to protect against water loss
- Further investigation, at a molecular level, of the physiological mechanisms by which plants adapt to extreme environments

Such research, when combined, will lead to a much more complete understanding of drought tolerance in plants. And with the help of genetic engineering it will be possible to create plants with these traits, without the need for long and tedious breeding programmes (Pellegrineschi 2003).

It should be noted that there is some risk involved with using GM and drought resistant crops, such as genetic contamination and dependence on purchased seeds.

Ecotourism: Alternative income such as the introduction of eco tourism needs to be explored. Eco-tourism is environmentally responsible travel to natural areas, in order to enjoy and appreciate nature (and accompanying cultural features, both past and present) that promote conservation, have a low visitor impact and provide for beneficially active socio-economic involvement of local peoples (The Nature Conservancy 2009). It helps educate the traveler; provides funds for conservation; directly benefits the economic development and political empowerment of local communities; and fosters respect for different cultures and for human rights (Honey 2008).

Market access improvement: It is essential that market access is improved so that communities are able to access necessary food stuffs and sell livestock and agricultural products. When markets access is blocked, overall household food security is at risk.

Small – scale irrigation: The introduction of small – scale irrigation will limit communities dependence on rain fed agriculture practices and increase overall household food security and income. Depending on rain fed agriculture often leads to varied yields and risk overall household food security.

Value addition crops: The creation of value added products from agriculture crops already being grown in the region is a method of income production that could be utilized to limit dependence one

[3] The CGIAR is a strategic alliance of members, partners and international agricultural centers that mobilizes science to benefit the poor. They aim to achieve sustainable food security and reduce poverty in developing countries through scientific research and research-related activities in the fields of agriculture, forestry, fisheries, policy, and environment.

livelihood mechanism and increase income. Products such as medicinal plants and handicrafts are common in the region, and could be scaled up.

Zero grazing for peri-urban dairy and livestock: Zero grazing also called 'stall feeding' is an intensive dairy production system in which cattle do not graze but are confined in shed or stall where feed and water are brought to them. It is an intensive system that produces a large amount of milk from a small amount of land (MAAIF Uganda). This sedentary form of livestock holding and dairy production is important as normally pastoral populations begin to move towards more peri-urban areas. The desire for meat and dairy, and value added dairy products are a growing market opportunities that could be tapped in to. In addition, zero grazing will benefit agriculture directly as a readily available fertilizer (manure) will be integrated in to agriculture production. This input will help decrease conflict for fertilizer and other inputs as a natural input will be in ready supply.

Institutional Based Opportunities

Commercial cooperative mechanism: Communities can set up agriculture cooperatives that allow farmers in the village to produce and transport crops collectively in order to earn money that can be used to purchase food during periods of need.

Early warning systems: The current existence of uncertainty/variability makes it difficult for affected communities to institute adaptation measures and technologies in a timely and effective manner, thus the need for early warning systems and improved climate information. In addition, a security strategy for food and fodder needs to be developed that allows a timely response to minimize death, suffering, and the undermining of pastoral livelihoods during and after droughts and other disasters (GL-CRSP 2004). With the addition of early warning systems, livestock rearing and farming can be aided by the use of models, satellite imagery, and better forecasts (United Nations Early Warning Programme 2007).

Market – based risk management:

Market – based risk management mechanisms such as 'insurance'-related instruments that spread and pool risks are important for supporting risk reduction, compensation and adaptation to climate-related and other disasters in developing countries.

Weather 'Insurance': In 2006, the World Food Programme partnered with French insurance firm Axa Re to pilot a programme to provide cash payouts to farmers in the event of a severe drought. Now, they are working with the Ethiopian government to expand the programme for three years from 2009 (IRIN 2006). Even though there was no payout in 2006, due to good rainfall, the programme was deemed a success by WFP for its innovative approach to risk management. In the event of a drought, Axa Re would have paid US$7.1 million to WFP, which would then have transferred the funds to the Ethiopian government to be disbursed as cash assistance to households. Programmes like this can work and need to be increased to determine the relative success they will have in different regions.

Another example from the World Bank Commodity Risk Management Group (CRMG), Malawi has introduced an innovative pilot drought insurance program for local groundnut farmers that will help them mitigate the risks associated with periodic droughts. The insurance will help farmers obtain financing necessary to obtain certified seeds, which produce increased yields and revenues as well as greater resistance to disease. The program is currently being utilized through the pilot program by nearly 900 farmers in four areas and, if successful, can be scaled up to other crops and other areas of Malawi and Africa (Walker 2005). CRMG piloting has shown that weather insurance for farmers in developing countries is feasible. It is important that the process is owned locally to insure sustainability and scalability of the programme.

Migration: For many people in this zone, however, migration to more fertile and less moisture-stressed areas to engage in farming or nonfarm activities is the only sustainable livelihood strategy. This is seen as a last case scenario, but is quickly becoming a reality to many people. As the stresses on the land continue to increase, many more farmers will be forced to migrate to more fertile land, causing problems as these farmers begin to compete with each other for natural resources and land.

Sub-Humid Zone Adaptation Measures

Being that the sub-humid zone is dominated by agriculture activity, many of the adaptation measures will be similar to that of the semi-arid. Under 'normal' periods there is enough moisture to maintain crop growth; therefore the sub humid zone has the greatest potential for increased livestock production. While this zone's high arable potential will be exploited primarily for food crop production, sedentary livestock and dairy production is becoming an increasingly viable option as more people leave their pastoral livelihoods for a more sedentary existence in urban and peri-urban areas.

Agriculture is primarily about adapting to climatic conditions. For many centuries, farmers have been pushing environmental limits where they grow their crops. Therefore, they have many arrows available in the quiver of adaptation measures to climate change. At any rate, adaptation of agriculture to climate change will assume many dimensions; innovations based on new science and technology will have to be combined with adaptive measures in the socioeconomic, institutional, and cultural/anthropological areas. The capacity for adapting to climate change will probably be more related to the successful implementation of such adaptive measures than to the scientific innovations.

The following are some recommendations for climate change adaptation activities that should be considered in the sub-humid zone. Many of the adaptation measures are similar to the semi-arid zone as both practice agriculture in varied degrees:

Natural Resource Based Opportunities

Agroforestry: Agroforestry is a collective name for land use systems and practices in which woody perennials are deliberately integrated with crops and/or animals on the same land management unit. The integration can be either in a spatial mixture or in a temporal sequence. There are normally both ecological and economic interactions between woody and non-woody components in agroforestry (ICRAF 1993). This use of integrated approach of using interactive benefits from combining trees and shrubs with crops and/or livestock should be considered (USDA-NAC 2009).

Better land management/Conservation Farming: Using improved methods of land husbandry to enable resource managers to better conserve soil, water, and the integrity of natural and managed ecosystems is needed. Farmers who practice conventional farming methods on degraded soils are highly susceptible to the threat of climate change and total crop failure even in seasons of moderately poor rainfall. They are also excessively dependent on increasingly expensive fertilizers which are now unaffordable for the majority. Practicing better land management techniques such as retention of crop residues, restricting tillage, completion of land preparation in the dry season, establishment of a precise and permanent grid of planting basins, planting furrows or contoured ridges, early and continuous weeding, rotation and intercropping, dramatically increase their yields, diversify their production base and engage in economic activity, regenerate their soils and sustain adequate levels of production in all but the worst droughts, liberate themselves from dependency on food aid and excessive use of costly external inputs, practice sedentary agriculture on a sustainable basis, and regenerate rather than exploit the environments in which they live.

Fodder banks: Fodder banks and zero grazing are two ways to limit livestock movement. Fodder banks are plantings of high-quality fodder species in order to maintain healthy productive animals. They can be utilized all year, but are designed to bridge the forage scarcity of annual dry seasons. Fodder banks do not provide 100% of feed requirements, but supplement the available dry season forage (FACT Net 1994). Zero grazing is an intensive dairy production system in which cattle do not graze but are confined in shed or stall where feed and water are brought to them. The combination of these two will limit movement of livestock allowing for re-growth of vegetation and decrease land degradation.

Marked Based Opportunities

Agribusiness: Agribusiness is a generic term that refers to the various businesses involved in food production, including farming and contract farming, seed supply, agrichemicals, farm machinery, wholesale and distribution, processing, marketing, and retail sales. Small scale agribusiness could create new livelihoods and increase.

Diversification of livelihoods: Diversification of agricultural livelihoods is important given the stresses on agricultural communities and the growth in population. The need to diversify livelihood activities should also include non-agricultural cash generation activities such as animal holdings and small businesses. Agricultural communities need to further diversify their livelihoods, both within the agricultural system (introduction of drought resistant varieties and new crops), as well as finding new and innovative ways to make a living.

High-yielding, drought-resistant varieties: Dependent on agricultural production for there survival, drought resistant modern seed varieties are very important to the population of the sub-humid zone. While high-yielding varieties do currently exist for most of the crops cultivated in the sub-humid zone (such as maize, sorghum, millet, soybean, and cowpeas), they are not widely adopted, especially in areas with poor market access and low precipitation. The high costs of fertilizers required for these high-yielding varieties erode their profitability, especially since the removal of fertilizer subsidies. In addition, demand for food by the non-agricultural sector is weak because of limited urban demand, insufficient exports, and cheap food imports. Therefore, to realize the potential of the zone, modern, stress-resistant varieties that respond well to small amounts of external inputs are needed. Crops with shorter growing seasons will also be important as season variability is becoming more common. These varieties must also meet local tastes so that they can satisfy farmers as well as domestic urban markets or export needs.

Introduction of Aquaculture: Diversification of agricultural livelihoods may also lead to the introduction of aquaculture in areas where water is not a limiting factor. The farming of freshwater and saltwater organisms will give the populations another means of protein and a livelihood boost. Unlike fishing, aquaculture implies the cultivation of aquatic populations under controlled conditions. In order for this practice to have a chance at success, the amount of water available in the area for household use must be plentiful so as to allow for water to be used to cultivate fish. This practice may only be available to a select few areas where rainfall is not a limiting factor.

Introduction of livestock holding: The introduction of livestock holdings in the more fertile sub-humid zone can be seen as an adaptation measure as communities will be able to diversify their diets and economic gains. While pastoral communities will have trouble maintaining a herd in the arid zone, the climate and amount of ground cover needed to keep animals is well suited for the sub-humid zone

Improved agricultural techniques/inputs: It is essential that improved agricultural techniques and inputs are introduced in the region if crop production is to increase in order to meet the growing populations demand.

Improved water management and irrigation: Investment in water control is need to be planned and implemented in the much broader framework of agricultural and rural development, where production, markets, finance and infrastructure are conceived in an integrated way and are mutually supporting. Policies and institutional frameworks must also be created in order to ensure fair and equitable access to water resources and effective access to markets for agricultural products. In addition to water management, an increase in the use of irrigation technology will help take a lot of the guesswork out of agriculture production and allow for more effective use of this scarce resource. Irrigation for crop production will not only increase reliable crop production, but will limit the water that is used and allow for water that was previously used for crop production to go towards other household needs.

Box 2: Adaptation options identified under Assessments of Impacts and Adaptations to Climate Change (AIACC) Project

- ✓ **Adaptation measure to water** stresses during droughts and high rainfall variability include: irrigation water transfer, water harvesting and storage: (in Gambia and South Africa (Nkomo et al 2005) and in Sudan (Osman et al 2005)). Measures specifically for agriculture include: planting of drought resistant varieties of crops, labor migration, changes in farm location, reduction in herd and farm size, improved water exploitation methods (e.g. Shallow wells), and food storage. Others include crop and animal diversification, income diversification, selling of assets, early maturing cops, high yield varieties, herd supplementation and sedentarization, and culling of animals (practiced in Nigeria and Mali (Dube et al 2005) and in Sudan (Osman et al 2005)).

- ✓ **Adaptation measure for heat waves** include: heat resistant cultivars; crop management (shorter season or early maturing crops, shifting time or location, change type of crop, shading both crops and animals, increase irrigation); and early warning and forecast systems (Adejuwon et al, 2005).

(http://www.aiaccproject.org/about/about.html))

Institutional Based Opportunities

Micro - Credit: Small credit program can also be utilized to allow for farmers to borrow money for seeds and fertilizer in times of need. These micro-loan programs have taken off in recent years but are mainly focused on women groups and small business development. A focus on agriculture is needed if crop production is to continue in light of climate change.

Migration: Similar to the other two zones**,** migration to more fertile and less moisture-stressed areas to engage in farming or nonfarm activities is the only sustainable livelihood strategy. In addition to moving to more fertile land, we are certain to see a rising number of people moving to urban and peri-urban areas. With this move comes different vulnerabilities and stresses that will change the way people live, and how livelihoods are made. This move will also present more opportunities including various new livelihood methods.

8. Conclusions

Moving forward it is critical to understand and react to the challenges facing the drylands in Sub-Saharan Africa. The most vulnerable communities to the impacts of climate change inhabit the dryland areas and the implications are significant. With the projected impacts of climate change; including on ecosystems, water availability, agriculture, and the pastoral communities on the whole, practical adaptation measures including policies which will build the resilience of communities to climate change are more important than ever. Without adaptation efforts to the threats of changes in climate, the people of the drylands may be forced to consider other livelihood options, including migration, in order to cope with the extreme changes.

It is important to note in identifying adaptation strategies and actions that the means to food security in every community will vary from place to place. Household food security will be a function of what activities make up their livelihood and each agro-ecological zone will have separate challenges to maintaining food security in light of climate change and desertification. It must be understood that with increased climate change and desertification, it is expected that these zones are going to shift causing many livelihoods to change and forcing the population to adapt, with various possible degrees of effectiveness. Ensuring food security and livelihoods is paramount as the looming threat of climate change threatens to alter the landscape and environment of the drylands of Africa. To this end, it is more important than ever that we look toward adaptation measures to ensure livelihoods and food security of these populations remain regardless of climate change and weather variability that is becoming a more consistent threat in these agro-ecological zones.

Despite popular belief of a generally low adaptive capacity in Africa, communities can adapt and change practices if their ways of life are to continue. Whilst there are many limitations in drylands, drylands livelihood systems are inherently opportunistic. Introducing or upscaling adaptation measures outlined in this paper, many of which are not foreign to the affected populations, would be a start, but their effectiveness will depend on a judicious selection, an integrated approach and longer planning timeframes, together with an enabling policy environment which reinforces actions at local and higher scales.

This paper and a policy brief version are available at the CSD-17 website and will also be available at www.undp.org/drylands. For more information, please contact eric.patrick@undp.org.

This paper is one of a two part set of UNDP-UNEP-UNCCD papers; the other paper addresses Climate Change Mitigation options in the drylands of Africa, with an emphasis on the potential for carbon sequestration.

9. References

1) Adejuwon, James and Obafemi Awolowo, (2005). Food Security and Climate Change in Sub-Saharan West Africa.

2) African Commission, 2005. Our Common Interest. Report of the Commision for Afruca. UK Government, London.

3) African Union Commision and NEPAD, 2006. Summit on Food Security in Africa. Dec 4-7 2006. Abuja, Nigeria.

4) Administrative Committee on Coordination: Sub-Committee on Nutrition (ACC/SCN) (2000*), 4th Report on the World Nutrition Situation*. Geneva: United Nations ACC Sub-Committee on Nutrition. January

5) Anderson, S. 2008. *Climate change –how will it affect drylands*? Haramata 53, IIED. May, 2008.

6) Boko, M., I. Niang, A. Nyong, C. Vogel, A. Githeko, M. Medany, B. Osman Elasha, R.

7) Brooks, N., 2006. *Climate Change, Drought and Pastoralism in the Sahel.* Discussion note for the World Initiative on Sustainable Pastoralism. http://www.iucn.org/wisp/documents_english/climate_changes.pdf

8) Campbell, D.J., (1977). 'Strategies for coping with drought in the Sahel: A study of recent population movements in the Department of Maradi, Niger.' Unpublished Ph.D. Dissertation, Clark University, Worcester, Masss

9) Commercialised Dairy Farming in Peri-urban Areas Through Zero-grazing of Cattle Meat and Dairy Division, Department of Animal Production and Marketing Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) P.O. Box 513, Entebbe

10) Dietz K, T. and Geest, V.D. and (2004). A literature survey about risk and vulnerability in drylands, with a focus on the Sahel. In: The Impact of Climate Change on Drylands, With a Focus on West Africa.

11) Dube O. P. and Pickup, G. (2001). Effects of rainfall variability and communal and semi- commercial grazing on land cover in southern African rangelands. Climate Research, Special Issue August 15, 2001 17:195-208.

12) Food and Agriculture Organization (FAO) Land and Water Division *Soil and Water Conservation in Semi-arid Areas*. Soil Resources, Management and Conservation Service Division Food and Agriculture Organization of the United Nations Rome, 1987

13) FAO 2002. *The State of Food Insecurity in the World 2001*. Rome.

14) FAO 2008. Climate change adaptation and mitigation in the food and agriculture sector. High Level Conference on World Food Security – Background Paper. HLC/08/BAK/1. FAO. (ftp://ftp.fao.org/docrep/fao/meeting/013/ai782e.pdf.)

15) Global Livestock Collaborative Research Support Program. *Improving Pastoral Welfare in Ethiopia and the Role of the Pastoral Affairs Standing Comimittee (PASC).* Research Brief, PARIMA, 2004.

16) Honey, Martha (2008). *Ecotourism and Sustainable Development: Who Owns Paradise?* (Second Edition ed.). Washington, DC: Island Press. pp. 33. ISBN-10: 1597261254 ISBN-13: 978-1597261258.

17) International Development Research Centre (IDRC) and Department for International Development UK (DFID), 2007-2008: CCA Annual Report. Enhancing African Adaptation to Climate Change.

18) Intergovernmental Panel on Climate Change (IPCC) Working Group I (AR4, 2007) [6], Summary for Policymakers, Footnote 1.

19) IRIN: Humanitarian news and analysis: *Africa: Rainwater harvesting could solve water shortages*, 2006.

20) Inter-Agency Task Force on Disaster Reduction (IATF/DR): On better terms: A Glance at Key Climate Change and Disaster Risk Reduction Concepts, 2006.

21) Millennium ecosystem Assessment (MeA). 2005. Ecosystems and human Well-Being: synthesis. 155 pp. Washington, D.C., island Press.

22) Nkomo, Jabavu, C. and Gomez, Bernard, 2006. Estimating and Comparing Costs and Benefits of Adaptation Projects: Case Studies in South Africa and the Gambia.

23) Osman Balgis N.G. Elhasssan, H. Ahmed, and S. Zakieldin, 2005. Sustainable Livelihood approach for assessing community resilience to climate change: case studies from Sudan. Working Paper No.17 (AIACC Project No. AF14).

24) Osman Balgis- Elasha,, Mahmoud Medany, Isabelle Niang-Diop, et al., 2006. *Background Paper on Impacts, Vulnerability and Adaptation to Climate Change in Africa*. Prepared for the African Workshop on Adaptation (Accra, Ghana).

25) Oxfam Briefing Paper, *Survival of the fittest: Pastoralism and climate change in East Africa*, August, 2008

26) Pellegrineschi, Alessandro , 2003. *Drought-resistant GM crops: a promising future*, International Maize and Wheat Improvement Center (CIMMYT).

27) Randerson, James, 2008. *Drought resistant GM crops ready 'in four years'* Guardian newspaper, UK.

28) Rosenzweig, C., G. Casassa, D.J. Karoly, A. Imeson, C. Liu, A. Menzel, S. Rawlins, T.L. Root, B. Seguin, P. Tryjanowski, and C.E. Hanson, 2007: Assessment of observed changes and responses in natural and managed systems. In *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. M.L. Parry, O.F. Canziani, J.P. Palutikof, and P.J. van der Linden, Eds. Cambridge University Press, pp. 79-131.

29) Swift, J. J. (1989), 'Why are rural people vulnerable to famine?', IDS Bulletin, 20 (2), 8-15.

30) Swift, J. (1998), 'Factors influencing the dynamics of livelihood diversification and rural non-farm employment in space and time,' Chatham: Natural Resources Institute.

31) Swift, J., C. Toulmin and S. Chatting (1990), '*Providing Services for Nomadic People: A Review of literature and Annotated Bibliography, UNICEF Staff Working Paper No. 8*, New York: WHO/UNICEF Nutrition Support Programme, UNICEF.

32) The Nature Conservancy 2009. *What is Ecotourism*

33) United Nations Convention to Combat Desertification (UNCCD). 2009

34) United Nations Environmental Programme (UNEP): *Africa Environment Outlook 2 – Our Environment, Our Wealth (AEO-2).*2006

35) UN International Early Warning Programme UN (2007). *UN-led global early warning system takes shape*. http://www.unisdr.org/ppew/iewp/media.html, accessed 2007-08-31.

36) The United Nations Framework Convention on Climate Change (UNFCCC) Article 1. Rio de Jineiro. 1992

37) UNFCCC Database on Local Coping Strategies http://maindb.unfccc.int/public/adaptation

38) United Nations Sudano-Sahelian Office (UNSO) 2002. Drylands: an overview.

39) United States Department of Agriculture (USDA) National Agroforestry Center (NAC). 2009

40) Walker, Courtland, 2005. *Malawi Pilots Drought Insurance Coverage with Local*

41) World Agroforestry Centre (ICRAF) 1993

42) World Initiative for Sustainable Pastoralism (WISP) Policy Note No. 04, 2007. Pastoralists as Shrewd Managers of Risk and Resilience in the Horn of Africa

Appendix 1: "Normal" pastoral coping adaptive livelihood strategies

During 'normal' situations, pastoralists use a series of coping strategies to survive a drought or other crises and limit vulnerability to shocks. Common features of the coping strategies of pastoral societies are that (Campbell 1977):

- They are integral components of the socio-economic system. They are maintained continuously but assume critical importance during periods of hardship.
- They tend to be adopted in an identifiable sequence in response to worsening conditions. Initially strategies are used which involve little disruption on the socio-economic system but as shortages intensify so productive assets (such as cattle) are sold and eventually abandonment of herding may be necessary.
- Not all members of a community are equally affected. Wealthier members may be more able to withstand a crisis than the poor; the old and the young may be more vulnerable to food deficits; and as men migrate in search of wage employment women's roles and responsibilities change.
- The strategies available to societies change over time. New opportunities arise and some existing ones may decline

In order to mitigate risks in variable and unpredictable rangeland environments, Pastoralism provides a highly flexible and adaptive livelihood strategy. It incorporates a variety of risk management strategies and resilience enhancement mechanisms as follows (WISP 2007):

- Livestock mobility: mobility optimizes the use of range, using large " diverse ranges comprising wet, dry and drought time grazing areas managed as common property
- Livestock density: diverse herds and flocks (grazers and browsers) reduces risk from disease, drought and parasites
- Maximizing stock densities: stock accumulation helps to ensure long term survival after drought stock loss
- Redistributing assets: mutually supportive relationships and support networks are critical for coping with crises
- Livelihood diversification: mitigating risk from drought may involve diversification into distant labor or trading markets
- Herd splitting: herd splitting spreads risks and enables systems of strong social relations and security to be maintained
- Use of wild foods: households may gather foods in order to supplement reduced yields during droughts
- Opportunistic cultivation: rain-fed or flood recession agriculture is practiced to spread risk

Appendix 2: Anticipated Impacts of increased land degradation and climate change on agro ecological specific livelihoods	
Arid agro ecological zone	Because of their dependence on markets for food, pastoralists' food security is affected by fluctuating market prices for commodities and overall shortages, as is currently being experience. What happens to agriculture products around the world will have a direct effect on the population in arid zones. Furthermore, substantial economic dependence on livestock has important consequences for food security. On the positive side, this gives households the flexibility to move away from potential problems, which can contribute to household food security. On the negative side, however, it can create new sorts of vulnerabilities for pastoral households. Two of the most important are the timing of seasonal economic and nutritional stresses, and the increased dependence of market exchange for acquiring staple foods. Dependence on the market for a substantial part of the daily calorie intake makes pastoralists vulnerable to changing prices of the products they sell (live animals, milk, animal products like hides, skins and wool) and the cereals they buy (Swift 1998). Cereal prices change in response to such supply-side factors such as the success of the harvest, remaining farmer and trader stocks, prospects for the current cropping season; and demand-side factors which include urban and pastoral needs, and livestock prices; which change in turn according to such supply-side factors as the success of the breeding season, alternative sources of pastoral nutrition, herd-owners' expectation about pasture availability in the forthcoming dry season, and demand-side factors such as seasonal live weight and condition of the animals, and cash income of purchasers such as farmers and urban people (Swift 1989). These pastoral terms of trade are volatile and will only get more volatile with the threat of increased climate change and desertification. Indeed, one need to look at the pastoral term of trade during a drought to see what effect climate change and desertification will have on the livelihoods of these pastoral communities.
Semi-arid agro ecological zone	Similar to the pastoralist communities in the arid zone, the health of their animals, the amount of rain they receive, and the overall environment also play vital roles on the success of the livelihood systems and overall food security. With increased climate change, rain will become more variable and introduction of new livestock diseases may occur. The agriculture aspect of their livelihood will be challenged the same as the population of the sub humid zone.
Dry sub-humid agro ecological zone	With increased climate change, the amount of rain and soil moisture *via* evapo-transpiration that will be available will decrease. Heat stress on crops and increased pest, disease and weeds will also be prevalent. These changes will result in reduced yields and increased overall volatility. In simple terms, the amount of food that is able to be produced will decrease. This effect will trickle down to all aspects of food security from the producer to the worker who makes his/her livelihood on other peoples' farms. Taking climate change out of the equation, enough food could be produced to feed the population. With the growing threat of climate change and desertification, steps need to be taken in order to ensure enough food is being produced, and food security is maintained. Furthermore, the change in scale effect – time and space- means that techniques which had worked in the past may no longer work and/or may need to be modified. This will require the combined efforts of affected communities, government and diverse development partners.

Appendix 3: Livelihoods/Food Security Challenges and Possible Adaptation Measure by Dryland Agro-ecological Zone

	Arid agro-ecological zone	Semi-arid agro-ecological zone	Dry sub-humid agro ecological zone
Livelihood challenges	This zone is characterized by low moisture availability and lack of vegetation cover owing to a combination of low annual rainfall (less than 500 millimeters), high potential evapo-transpiration rates and often shallow, saline and calcareous soil. With limited supplies of permanent pastures and water, nomadic and transhumant pastoral systems based on communal grazing are the dominant farming systems. Changes in rainfall patterns and growing pressure on land and associated land degradation have been adding to stress on the already vulnerable livelihoods of pastoralist societies. Increased aridity, climatic variability and hazards, such as prolonged droughts, often induce malnutrition and/or disease of livestock due to unavailability of sufficient fodder and deterioration in pastoral lands, which lead to reduced willingness of traders to purchase animals in poor conditions. Fluctuating market prices of livestock products and feed as well as overall shortage of commodities in turn affect pastoralists' food security markedly due to their high dependence on market exchange for acquiring staple foods. Competition and conflicts between pastoral communities and with other groups over scarce and scattered resources are also on the rise.	This zone receives 500-1,000 millimeters of rainfall annually with a growing period of 3 to 6 months. Dwellers are typically agro-pastoralists, while, with varying balance between drought-tolerant crops production and livestock rearing. Due to the poor soils deficient in nitrogen and phosphorus and limited precipitation, crop production is mainly for subsistence purposes, except some cash crops, with few resources devoted to livestock production. While agro-pastoralists still rely on markets for cereals and other products not produced domestically, they have higher flexibility in the sale of livestock, compared with arid zone. Conversion of rangelands to cultivated lands in areas that do not have an adequate level of provisioning and supporting services, notably water and soil fertility, and inadequate dryland irrigation and cultivation practices, has resulted in severe soil salinization and erosion (MEA, 2005). Climate change could further reduce water availability in the semi-arid ecosystem and in turn spur the spread of land degradation and reduction of primary production. Conflict already occurs between herdsmen and farmers in semi-arid regions (IPCC, 2001).	This zone consists of savannah type vegetation which receives between 1,000 and 1,500 millimeters of rainfall annually with a growing period of 6 to 9 months. While mixed crop-livestock farming is partly practiced, the predominant livelihood is subsistence and smallholder agriculture, largely rain-fed. A wide array of food and forage crops are grown including maize, millet, sorghum, cassava, yam, groundnut, cowpeas and leguminous forages. Climate induced uncertainty associated with inter and intra seasonal rainfall variability remains a fundamental constraint to agricultural production. While empirical data are still limited, potential impacts of climate change are likely to make the situation worse with decreased rain, reduced soil moisture due to higher evapo-transpiration rates and increased heat stress associated with higher temperatures, on crops, pest, disease and weeds. These changes in scale effect – both in terms of time and space – will result in diminished yields and higher overall volatility, which trickles down to all aspects of food security chain from consumers, land owners, and all the way to landless farmers who make a livelihood on other peoples' farms.
Natural Resource Management Based Adaptation Opportunities	• Herd management • Home gardens • Rainwater harvesting • Soil and water conservation	• Agroforestry • Conservation agriculture • Cropping pattern adjustment • Improved tree management and planting • Rainwater/groundwater harvesting • Soil and water conservation	• Agroforestry • Better land management/Conservation farming • Fodder banks • Rainwater/groundwater harvesting • Soil and water conservation
Market Based Adaptation Opportunities	• Drought resistant/tolerant breeds (e.g. camel) • Diversification of livelihoods (e. g. honey production) • Eco-/cultural-tourism • Exchange of livestock for agriculture commodities and *vice versa* • Livestock feed supplementation and fattening • Livestock products value addition (e.g. hides and skins) • Market access improvement • Management of livestock diseases	• Agribusiness • Diversification of livelihoods • Drought-tolerant crop varieties • Eco-tourism • Market access improvement • Small-scale irrigation • Value addition (e. g. medicinal plants; handicrafts) • Zero grazing for livestock and dairy production	• Agribusiness • Diversification of livelihoods • High-yielding, drought-tolerant crop varieties • Introduction of aquaculture • Introduction of livestock holding • Improved agricultural techniques/inputs • Improved water management/irrigation • Value addition
Institutional Based Adaptation Opportunities	• Commercial cooperative mechanism • Conflict resolution and security reinforcement • Extension and education • Micro-credit • Migration • Pastoral passport	• Commercial cooperative mechanism • Early warning mechanisms • Extension and education • Micro-credit • Migration • Market – based risk management: weather 'insurance'	• Commercial cooperative mechanism • Extension and education • Micro-credit • Migration • Market – based risk management: weather 'insurance'