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CLIMATE CHANGE IN THE AFRICAN DRYLANDS:

OPTIONS AND OPPORTUNITIES FOR ADAPTATION AND MITIGATION

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Acronyms

AIACC	Assessments of Impacts and Adaptations to Climate Change Project
AR4	Fourth Assessment Report (of the IPCC)
AUC	African Union Commission
AUA-NEPAD	AUC-New Partnership for Africa's Development
CBD	Convention on Biological Diversity
CDM	Clean Development Mechanism
CGIAR	Consultative Group on International Agricultural Research
CIMMYT	The International Maize and Wheat Improvement Center (in Spanish: Centro Internacional de Mejoramiento de Maíz y Trigo, CIMMYT)
CRMG	Commodity Risk Management Group (World Bank)
DDC	Drylands Development Centre (UNDP)
DLDD	Desertification, Land Degradation and Drought
ECCM	Edinburgh Centre for Carbon Management
ECOWAS	Economic Community of West African States
ESPA	Ecosystem Services and Poverty Alleviation
ECCM	Edinburgh Centre for Carbon Management
FAO	Food and Agriculture Organization of the United Nations
GL-CRSP	Global Livestock Collaborative Research Support Program
Gt	Giga Ton
IAASTD	International Assessment of Agriculture Knowledge, Science and Technology
ICRAF	World Agroforestry Centre
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IGPB-DIS	International Geosphere-Biosphere Programme-Data and Information System
ILRI	International Livestock Research Institute
IPCC	Intergovernmental Panel on Climate Change
IRIN	Integrated Regional Information Networks
LADA	Land Degradation Assessment in Drylands
LULUCF	Land Use, Land Use Change and Forestry
MA	Millennium Ecosystem Assessment
MDG	Millenium Development Goals
NRM	Natural Resource Management
SAT	Semi Arid Tropics
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNDP/DDC	United Nations Development Programme - Drylands Development Centre
UNDP/EEG	UNDP's Energy and Environment Group
UNEP	United Nations Environment Programme
UNEP-WCMC	UNEP- World Conservation Monitoring Centre
UNFCCC	United Nations Framework Convention on Climate Change
UNIEWP	United Nations International Early Warning Programme
UN–REDD	United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries
UNSO	United Nations Sudano-Sahelian Office
WFP	World Food Programme
WISP	World Initiative for Sustainable Pastoralism

Foreword

Africa is a vast mosaic of diverse and contrasting landscapes, plant and animal species, and human populations leading very different and unique lifestyles. However, when we look at the entire continent we tend to be struck by one significant characteristic: much of it is dry. The wettest areas are located around the forest belts of West and Central Africa and a few highland areas. Outside those parts, Africa is largely covered by barren deserts, savannah, grassland, scrubland, woodlands and dry forests. Indeed, drylands comprise 43 per cent of the continent, and have a population of some 325 million people.

The people living in the drylands are heavily dependent upon ecosystem services directly or indirectly, for their livelihoods. But those services—from nutrient cycling; flood regulation and biodiversity to water; food and fibre-- are under threat from a variety sources such as urban expansion and unsustainable farming settlements. As a result these fragile soils are becoming increasingly degraded and unproductive. Climate change is now aggravating these challenges.

However, combating climate change and adapting communities to its impacts represents an opportunity for new and more sustainable investments and management choices that can also contribute to improved livelihoods and fighting poverty among dryland communities.

An ecosystem approach which includes restoration and renovation is one important direction that needs to be urgently undertaken.

For example evidence is emerging that carbon stocks in Africa are high and almost 60 per cent of the carbon contained in Africa's soil is found in the drylands. This carbon is widely and thinly spread, and is managed by some of the world's poorest people.

Establishing the 'ownership' of carbon which is distributed over so many millions of hectares of land and which is managed by so many people, communities and nations is not easy.

There is therefore a need for the right instruments to enable efficient carbon management in the dry parts of Africa, and for dryland populations to receive assistance in adapting to and mitigating the effects of climate change.

This paper highlights the climate change mitigation potential of the African drylands, and lays out various paths towards adaptation which should be supported to reduce the vulnerability of dryland populations, and increase their food security.

In particular, this paper highlights the need for a compact between donors, investors and inhabitants of the drylands, in which 'conventional' overseas development assistance increases and continues to play its important development enhancing role, but where additional adaptation funds flow to the poorest, and where carbon finance supports the millions of people directly involved in drylands land management.

The climate crisis is one of the greatest challenges our world faces – and indications are that climate change is taking place faster than previously predicted. There is an urgent need for stepped up efforts to adapt to and mitigate the effects of climate change. By highlighting the important contributions drylands can make to this end, it is our hope this publication will help advance this important agenda.

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Executive Summary

The drylands of Africa, exclusive of hyper-arid zones, occupy about 43 per cent of the continent, and are home to a rapidly growing population that currently stands at about 325 million people. Dry zones, inclusive of hyper-arid lands, cover over 70 per cent of the continent's terrestrial surface. Outside of the cities many dryland inhabitants are either pastoralists, sedentary or nomadic, or agro-pastoralists, combining livestock-rearing and crop production where conditions allow. Over millennia they have lived with variable rainfall and frequent droughts using a range of coping strategies, but changing circumstances mean that these traditional methods must be capitalized upon and enhanced. Unsustainable practices are contributing to significant land degradation, and it is predicted that climate change will further compound the already tenuous situation. Without significant efforts to address the impact of climate change and land degradation, the livelihoods of the African drylands populations will be in jeopardy.

There are many adaptation options, which, if adequately designed and applied in response to specific local contexts and realities, can limit the negative effects of climate change and land degradation on drylands livelihoods in Africa. Some are based on natural resource management (NRM), which combines land conservation and productivity enhancement practices, such as improved herd management, rainwater harvesting, and home gardens. Others are market-based, which aim to improve market access and increase incomes, thereby reducing vulnerability. Institutional options form a third category, focused on local-level structural change such as extension and education, micro-credit and migration. Many of these adaptation measures are already familiar to the inhabitants of the drylands, but their effectiveness now depends on careful selection and application, so that they are implemented in the right place and at the right time. An enabling policy environment is also critical for the adaptation options to be practised in a sustainable manner.

Land degradation is also a source of greenhouse gases. Addressing land degradation in dryland ecosystems therefore also offers climate change mitigation benefits. Drylands in Africa have a significant mitigation potential: changes in land management practices can lead to greater carbon sequestration, that is, removing carbon from the atmosphere. The carbon sequestration potential of the drylands is high, due to their large area and their current low carbon content. With the right incentives and support to manage drylands for carbon sequestration, their inhabitants could make a great contribution to the mitigation of contre global climate change crisis.

The key to realizing this potential is to recogize the continuing need for poverty alleviation support in the dry parts of Africa, and also to recognize the importance of carbon sequestration in drylands soils and link drylands management to carbon markets, so that custodians of dryland ecosystems have incentives to manage them for long-term carbon sequestration compensation. However, current carbon markets recognize very few potential kinds of carbon finance projects in most

parts of drylands. There are also methodological constraints that need to be addressed. Under these circumstances, carbon prices will remain low.

Carbon markets are likely to develop more rapidly with greater financial backing than other markets for ecosystem services. Dryland landscapes should be integrated more effectively into global mitigation strategies. The realization of such interventions in African drylands, supported by adequate development assistance and carbon-financing, promises multiple co-benefits that contribute to the global mitigation of climate change, while safeguarding dryland communities' livelihoods through improved ecosystem services for food security, biodiversity and water provisioning and regulation as well as enhanced ecosystem function and resilience.

Definitions and Explanations

Adaptation is the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effect, which moderates harm or exploits beneficial opportunities.

Adaptive capacity is defined by the Intergovernmental Panel on Climate Change (IPCC) 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.

Coping mechanisms are strategies that have evolved over time through people's experience in dealing with the known and understood natural variation that they expect over the seasons, combined with their specific responses to a season as it unfolds.

Adaptive strategies are longer-term (beyond a single season) strategies that allow people to respond to a new set of evolving conditions (biophysical, social and economic) that they have not previously experienced. The extent to which communities are able to respond successfully to a new set of circumstances will depend upon their adaptive capacity.

Climate The statistical description in terms of means and variability of key weather parameters for a given area over a period of time – usually at least 30 years.

Desertification 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's surface, as opposed to aridity, which is a climatic condition.

Drylands refer to all terrestrial regions where the production of crops, forage, wood and other ecosystem services is limited by water (MA, 2005), which encompass all lands where the climate is classified as dry, dry-sub-humid, semi-arid and arid, exclusive of hyper-arid areas. This is the definition adopted by the UNCCD according to an aridity index: the ratio of mean annual precipitation to mean annual potential evapotranspiration.

The Convention on Biological Diversity (CBD) definition of drylands' used within its Programme of Work on Dry and Sub-humid Lands (UNEP/CBD/SBSTTA/5/9) differs from the UNCCD definition in two ways:

i. It includes hyper-arid zones (UNEP/CBD/SBSTTA/5/9), which represent approximately 6.6 percent of the Earth's land surface.
ii. Major vegetation types are used to define dryland areas in addition to those defined according to the aridity index (UNEP/CBD/SBSTTA/5/9).

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 complex, trans-boundary and multifaceted including biophysical, socio-economic, political, demographic, gender and other dimensions. In general, three key indicators are used to measure the level of food insecurity, namely: availability, access and utilization.

Mitigation refers to the elimination or reduction of the 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.


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Introduction

Home to over 2 billion people living in some 100 countries, drylands cover more than 40 per cent of the earth's surface. In Africa, 43 per cent of land is estimated to fall within the drylands. According to the latest statistical data available, the population of the African drylands is approximately 325 million, and growing faster than the global average (UNSO, 2002). Dry zones, inclusive of hyper-arid deserts, cover over 70 per cent of the continent's terrestrial surface. While less arid than deserts, drylands are characterized by low and erratic precipitation, high temperatures and high rates of evapo-transpiration.

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 centres, such as Cairo, Johannesburg and Kano, are located in these regions.

Cropping is by far the dominant source of livelihood in Sub Saharan Africa. However, livestock husbandry is important and many rural dryland dwellers make their living through pastoralism. They also use trees and forest products for fodder, timber, fuelwood, medicine, food and many other non-timber forest products. Drylands livelihoods represent a complex form of natural resource management, involving a continuous ecological balance between pastures, livestock, crops and people (WISP, 2007).

Inhabitants of drylands in Africa have learnt, over millennia, to cope with permanent water scarcity, variable inter- and intra-seasonal rainfall and the recurrent risks of weather-related shocks (Campbell, 1977; IAASTD, 2009). However, as a result of high poverty rates, changing socio-economic and political circumstances and demographic growth, traditional coping strategies are increasingly becoming insufficient. Unsustainable land management practices, including over-grazing, over-cultivation, illegal and excessive fuel wood collection and poor irrigation technologies among others, have become prevalent, often due to institutional or tenurial barriers. As a result, in the recent past some 320 million hectares – 25 per cent – of the already fragile African drylands have been further degraded in a process often referred to as 'desertification'. This has been compounded by poorly conceived policies and ineffective governance (UNEP, 2006).

Climate change adds another layer of risk to this precarious situation. Its impacts threaten to exacerbate the existing land degradation problem and add to the vulnerability of the drylands' inhabitants, unless significant measures are taken to improve management of the natural resource base (IBRD/World Bank).

This publication is organized in four sections. It starts by providing, in Section 1, background information on climate change and vulnerability in the African drylands. Section 2 provides an overview and analysis of key livelihood challenges confronting dryland populations. The analysis takes into account the projected impacts of climate change and ongoing land degradation on the three most prevalent dryland agro-ecological zones, namely arid, semi arid, and dry sub-humid. It also discusses 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 better anticipate and respond to potential impacts of desertification, exacerbated by climate change. In Section 3, the publication highlights carbon sequestration potential in drylands ecosystems. It provides data on the breakdown of carbon stored in drylands in each region, as well as on the comparison of total and drylands carbon stocks in all regions of the world. It also discusses how addressing land degradation in dryland ecosystems presents two complementary ways of mitigating climate change. Additionally, this section analyzes the current carbon markets and their limitations in relation to drylands ecosystems. It concludes with suggestions on the need to develop innovative packages for the drylands if these are to benefit from the carbon market. Section 4 provides the conclusions.

1. Climate change and vulnerability in the African drylands

Drylands are under constant threat from multiple stresses and challenges, which occur as a result of a complex interplay of natural processes (such as weather variability, recurrent and unpredictable droughts and the concomitant floods caused by the typically short and heavy intervening rains) and human-induced processes (including land degradation and desertification caused by unsustainable and inadequate land use practices on a fragile resource base of low fertility). These processes are fuelled by local forces, such as demographic pressure, poverty, high dependence on subsistence rain-fed agriculture, prevalence of HIV/AIDS and other infectious and chronic diseases, and civil conflict. They are also often driven by external forces, including inadequate governance mechanisms, ineffective land tenure systems and poorly conceived national policies, protectionism measures by developed countries, import restrictions and fluctuations in the world economy (MA, 2005).

The most common and serious result of these threats is chronic food insecurity. According to the African Union Commission's (AUC) Food Security Report, 27 per cent of the total population in Africa is undernourished; nearly half of the children of Africa suffer from stunting; and acute malnutrition (over 10 per cent) 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-NEPAD, 2006). The majority of the victims of food insecurity in the region are the poor

inhabiting the drylands who depend heavily upon natural resources for their livelihoods, either by growing crops or managing livestock.

There is considerable variability and uncertainty in current climate change projections. Nevertheless, there is now reasonable agreement from a number of different models, including the IPCC's Fourth Assessment Report (AR4) on Climate Change, that Africa is at the highest risk from climate change, given the magnitude of existing stresses in the continent (IPCC, 2007a). It is highly likely that in the coming years significant areas of the African drylands will see changing rainfall patterns with more frequent and more intense extreme events such as droughts and floods. Table 1 illustrates the projected changes in temperature, precipitation patterns and sorghum yields in different sub-regions of drylands in Africa as a result of climate change projections.

Increased temperatures are expected to add to water problems by causing additional loss of moisture from the soil. The AR4 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 per cent in some countries in Africa if production practices remain unchanged (IPCC, 2007a). These changes will place an additional pressure on already over-stretched food supply systems in the African drylands and undermine further the livelihoods of pastoralists and agro-pastoralists in drylands. It is worth noting, though, that the impact of increased temperatures on low input agriculture will be minimal as other factors will remain the dominant constraints (Cooper et al., 2008).

The people living in the drylands are heavily dependent upon ecosystem services directly or indirectly, for their livelihoods. But those services – from nutrient cycling, flood regulation and biodiversity to water, food and fibre – are under threat from a variety sources such as urban expansion and unsustainable farming settlements. As a result these fragile soils are becoming increasingly degraded and unproductive. Climate change is now aggravating these challenges (UNEP, 2009).

Table 1. Climate change projections in dryland regions in Africa[1]

IPCC 4th Assessment Report –Change from present to 2080-2099

Region and predicted changes in sorghum yields	Median projected temperature increase (c°)	Median projected precipitation increase (%)	Agreement on precipitation among models	Projected frequency of extreme warm years (%)	Projected frequency of extreme wet years (%)	Projected frequency of extreme dry years (%)
East Africa 20-48% yield increase	3.2	+7	Strong for increase in DJF. MAM. SON	100	30	1
Southern Africa 20-30% yield decrease	3.4	-4	Strong for decrease in JJA, SON	100	4	13
Sahara 20-30% yield decrease	3.6	-6	Strong for decrease in DJF, MAM	100	na	na

Adapted from Nassef et al. (2009), Cooper (2009)

[1] The letters in 3rd column stand for months of the year. Original source Inter-governmental Panel on Climate Change Fourth Assessment Report. Projection from current to 2080 - 2099


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Adaptation in the African drylands

Communities already have a long record of adaptation to climate variability. However, as previously mentioned, the impacts of climatic and other man-made stresses have been growing continuously at a rate that often exceeds human and ecosystem tolerance levels. Consequently many traditional adaptive knowledge and livelihood strategies practised in drylands for centuries no longer suffice or are inefficient (Boko et al., 2007). Efforts to reduce the vulnerability of drylands populations, therefore, must reinforce their risk management and coping capacities by augmenting existing adaptation mechanisms and supplementing them with new options that are tailored to the unique local contexts.

This section provides an overview of the key livelihoods challenges confronting the dryland populations in Africa in the face of climate change and the potential adaptation options to be promoted in three main drylands agro-ecological zones: arid, semi-arid and dry sub-humid zones. Adaptation options are identified as: (1) natural resource management (NRM)-based, (2) market-based, and (3) institutional, which could be implemented individually or simultaneously depending on the conditions on the ground. NRM-based options focus on the sustainable management of land, water, soil, plant and animal resources; market-based options are those that aim to improve market access and result in increased incomes, thereby reducing vulnerability;

while institutional options focus on local-level structural change such as extension and education, micro-credit and migration. All of this will require processes of dynamic change. Some places may become unsuitable for crop or animal production. New opportunities may emerge in other places.

It is important to note that the adaptation options outlined in this paper are not an exhaustive list, but are indicative of a range of possible measures, to help facilitate further discussion and exploration. Additionally, it is also critical to note that there are significant similarities and overlaps among the three drylands agro-ecological zones in terms of the livelihoods patterns and the nature and extent of the challenges people face. Thus, while different adaptation options are presented for different agro-ecological zones to avoid duplication, many are applicable across two or more zones.

Arid zones

Arid zones have low rainfall (200–500 mm/year) and soils are generally poor. These zones are therefore characterized by low water availability and little vegetation. The arid areas around the Sahara desert, for example, entered a period of prolonged desiccation approximately 7000 years ago. The inhabitants of this zone are mostly pastoralists or oasis dwellers who are dependent on trade in livestock and market access to purchase foodstuffs.

Pastoralism in Africa evolved in response to long-term climate variability and lack of reliable supplies of permanent water, and is by its very nature a form of adaptation to climate change. Pastoralism incorporates a variety of risk management strategies, and has helped people survive in an increasingly arid and unpredictable environment. For example, pastoralists move livestock according to the shifting availability of water and pasture to optimize the use of rangelands and maintain diverse herds including browsers and grazers (Brooks, 2006). In addition, they often employ mutually supportive networks to share risk. They also tend to reduce the possibility of total stock loss during extreme weather events by keeping large herds.

In the meantime, due to their high dependence on trade, pastoralists' livelihoods and overall food security could easily be at risk when their market participation is restricted by a number of hurdles: for instance, absence of livestock markets and sales outlets in close proximity, limited transportation options and market price fluctuations (Swift, 1998).

Relative to other land use practices in the drylands, pastoralism, given its mobility, is expected to function well even within the context of wide rainfall variability and unpredictability (Nassef et al., 2009). However, climate change poses the threat of spreading livestock diseases, as it influences insect vector habitats and populations that are likely to spread to new areas.

Arid zone adaptation options

NRM-based options

Pastoralists already employ sophisticated **herd management** techniques to ensure good productivity under today's harsh conditions. They require, for example: a) understanding of how to use grazing to stimulate grasses for vigorous growth and healthy root systems; b) using the grazing process to feed livestock and soil biota- through maintaining soil cover (plants and litter) and managing plant species composition to maintain feed quality; and c) providing adequate rest from grazing without over-resting the plants (Neely and Bunning, 2008). Nevertheless, they are often neglected by governments and donors under the erroneous assumption that pastoralism is archaic and inefficient. An important element of an adaptation strategy needs to be effective support for pastoralists' current ways of life. This strategy should be supplemented by more modern technologies and tools, including the increasing reliance on drought tolerant breeds of livestock species, such as camels, and the improvement of animal disease control services.

Livestock feed supplementation is common during droughts, and should be enhanced as an adaptation measure. Research is being carried out into improved fodder plant and tree species to increase livestock strength and milk production, which would improve productivity and resilience of both livestock and pastoralists in the event of increased floods and droughts (Oxfam, 2008).

Adaptation will also require improvements in **land and water management**. Rehabilitation of degraded rangeland will improve the penetration and storage of rainwater and enhance biomass production. Rangeland rehabilitation should always be accompanied by measures such as controlled grazing and retention of livestock manure on grazing sites for land fertilization to ensure that restored land does not become degraded again. Other techniques such as increased water infiltration, capturing of rainwater run-off and water storage in cisterns or behind small dams could also be applied more efficiently to improve water availability for people and livestock. In suitable areas, groundwater recharge using rainwater should be explored.

Market-based options

Pastoralists depend on being able to sell their animals and in return to buy stock and foodstuffs, such as cereals and legumes. An almost complete lack of functioning markets in arid zones limits pastoralists' ability to easily exchange animals for other food, often leaving little option for the pastoralists but to walk their animals long distances to markets. As they have no source of information on livestock prices, pastoralists are often paid poor prices by unscrupulous market agents.

The adaptation strategies for arid zones should, therefore, include a thorough **value chain analysis** and the **establishment of effective markets**. On one hand, these options will require investment in market infrastructure, building of slaughterhouses in or near arid areas, improvement of road connections, and installation of cold stores and refrigerated vehicles. On the other hand, support must be provided to promote **pastoralists' access to markets.** The organization of marketing and trading co-operatives, for example, enables pastoralists to enhance their collective bargaining power and benefit from economies of scale in the organization of services. Support also needs to be provided for improving balance in herd quality and quantity, to facilitate better predictions of the ways in which livestock values and sales will respond to climate and non-climate induced changes (United Nations Development Programme Drylands Development Centre (UNDP/DDC), 2008).

Pastoralists in remote arid areas have little access to financial services. As a result, they tend to keep reserves of assets in the form of large herds rather than money. The **provision of financial services** allows flexibility for livestock keepers, serving as a cash reserve for avoiding sudden disruptions to their livelihoods in difficult times. For example, emerging systems in Kenya and elsewhere that permit the transfer of money by mobile telephone are eliminating remoteness as an obstacle to moving money around.

Increasing human populations and the need to minimize their impacts on rangelands that are increasingly stressed by climate change will drive large numbers of people out of the conventional pastoral system. Pastoralists might **diversify their livelihoods** outside the livestock production sector, such as through small business development. Small businesses might begin by adding value to livestock products such as skins and hides. The establishment of new businesses will, of necessity, be a long-term endeavour. Improved education and health services will be vital to provide the healthy and educated people who will move into business.

Institutional options

Maintaining pastoral mobility will be a vital part of adaptation. A pastoral passport can provide an opportunity for pastoral communities to cross borders for grazing, without experiencing legal and bureaucratic difficulties. For example, the Economic Community of West African States (ECOWAS) has been providing pastoralists with Transhumance Certificates together with a handbook of travel to ensure their free mobility across the livestock corridors of ECOWAS member countries through designated entry points (GL-CRSP, 2004).

Meanwhile, a climate change adaptation strategy for the arid zone must recognize the inevitability of more **permanent migration** over time. Pastoral groups will increasingly shift away from the areas that are no longer viable, into zones that are less dry with more predictable rainfall patterns. Human migration induced by demographic pressure and environmental stressors is often accompanied by conflict between customary and statutory land tenure arrangements and services, and fuels tensions among multiple resource users (Anderson, 2008). It also tends to bring new and sometimes inappropriate land management technologies and methods that exacerbate an already volatile situation. Systematic **conflict mitigation and security reinforcement** systems therefore need to be put in place; these should be supported by robust land use and access policies and planning. In this process it will be particularly important to recognize the diversity and multiplicity of land management systems and leave room for dialogue and negotiation at the local level, while the state functions as a capable mediator and enforcer (Nassef et al., 2009).

Semi-arid zones

The semi-arid zones receive 500–1000 mm rainfall/year and have a growing period of 3–6 months. Inhabitants of this zone are typically pastoralists and agro-pastoralists, who make their livelihoods from a combination of crop cultivation and livestock rearing. Agro-pastoralists may produce a substantial part of the cereals, legumes and other food crops they require for subsistence. In reality, however, many are unable to grow sufficient food to feed the household and are engaged in off-farm work as a supplemental source of income or are dependent on remittances. Although there may be untapped production potential in some areas, poor soils, erratic precipitation and a lack of infrastructure tend to hinder investment in expanded production. (Ncube et al., 2009).

Agro-pastoralists have a long history of practising various coping strategies, especially in places where droughts recur, and have developed their own ways of assessing the prospects for favourable household or village seasonal food production. For example, home gardens and sheep fattening have long been practised by small farmers in Kordofan and Darfur States of Western Sudan, and contribute significantly to food security (Osman-Elasha et al., 2006). In many locations food crops have replaced non-food cash crops, and more drought resilient crop varieties have been introduced. Tribal and individual movements and migration are also practised broadly throughout Africa as viable adaptation options for income diversification purposes (Osman-Elasha et al., 2006).

However, the need to produce more food to meet the demands of an increasing population has led to overgrazing and conversion of rangelands to cultivated lands, even in areas that do not have adequate provisioning and supporting services, notably water and soil fertility. Unsustainable irrigation and cultivation practices in the semi-arid zone have resulted in severe soil salinization and erosion, which in turn leads to a reduction in food productivity and long-term food insecurity (MA, 2005). Climate change will exacerbate this situation, and will likely also lead to increased conflict between herders and farmers (IPCC, 2007a).

Semi-arid zones adaptation options

NRM-based options

Soil and water management is essential for maintaining the production of fodder and food crops under conditions with high water stress. Soil erosion may be controlled through the reduction of surface water run-off by improving soil surface cover or physical structures. Similarly, erosion will be reduced through the introduction of various techniques for preventing splash erosion, formation of crusts and breakdown of soil structure, all of which could also contribute to increased infiltration, improved soil fertility and water conservation (FAO, 1987; Peterson et al., 2006).

However, in reality, poor farmers are often reluctant to invest in improved soil and water management. They are unable to risk foregoing the immediate income generated by conventional land use practices in favour of long-term benefits (Berry et al., 2003). This emphasizes the need for climate change adaptation strategies to put in place incentives for investment in better management of soil and water.

Improved tree management and planting can help in holding soils together and reversing desertification processes. For example, in Senegal and Burkina Faso, local land users have adapted traditional pruning and fertilizing techniques to double tree densities in semi-arid areas. Although tree planting is not a new phenomenon, it is being undertaken in some dryland areas in a much more comprehensive way. Afforestation techniques, as shown in Box 1, are important in increasing land cover, as well as trapping moisture in the soil.

Cropping pattern adjustments may help farmers adapt to changing weather patterns. Crops can be planted further apart so that more moisture is available for each row, increasing the likelihood that they will survive a period of drought. Additionally, **conservation agriculture**, which encompasses the techniques of minimum mechanical soil disturbance, topsoil management for the creation of a permanent organic soil cover and crop rotation, is being increasingly applied with the aim of achieving both sustained agricultural production and environmental conservation. Important to crop production will be the renewed uptake of integrated farming systems that include livestock, crops and trees to maximize organic inputs, increase nutrient cycling, water holding capacity and productivity while increasing soil carbon sequestration.

Box 1: Afforestation through vegetative propagation – Growing Faidherbia albida in Burkina Faso, West Africa

The genus Acacia comprises many species that 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 quick growing but short lived – mostly for 12 to 15 years in suitable conditions. Yet some are proven to last much longer.

Virtually all Acacias are propagated from seed. However, a number of species have also been successfully propagated from cuttings and this trend can be expected to increase. Best results are achieved with cuttings of about 7.5–10.0 cm 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 another reproduction method for Faidherbia albida (syn. Acacia albida delile). The farmers succeeded in using Faidherbia albida to colonize their plots by cutting the roots to encourage production of 'root suckers'. These root-suckers grow and become adult trees within seven years, at which point the farmers cut the lateral roots again and other root-suckers appear.

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

Drought tolerant crops promotion is an indispensable tool in adapting to climate change. Some drought-resistant, fast-growing crops such as sorghum and chickpeas can thrive and yield relatively well even with high water scarcity within the shortened length of the growing seasons, as they mature before the depletion of soil moisture, thereby reducing the threat from dry spells (Dar, 2009). Research on drought tolerance has been widely conducted. For example, the International Maize and Wheat Improvement Center (CIMMYT) is investigating maize varieties that stall seed development during periods of drought in order to conserve water, or that are better at taking up water. Other varieties are being selected for their with drought tolerant characteristics such as their ability to accumulate sugars and salts to protect against water loss. Investigation is also underway at a molecular level into the physiological mechanisms by which plants adapt to extreme environments, in order to shed light on opportunities to improve drought and salt tolerance[2].

Research such as that carried out by the Consultative Group on International Agricultural Research (CGIAR) crop breeding institutes will lead to a much more complete understanding of drought tolerance in plants[3]. With the help of modern biotechnology it is possible to develop plants with these traits considerably faster than through traditional breeding programmes (Pellegrineschi, 2003).

[2] For more information, please visit http://en.wikipedia.org/wiki/International_Maize_and_Wheat_Improvement_Center
[3] For more information, please visit http://www.cgiar.org/impact/agribiotech.html.

The introduction of small-scale irrigation may reduce farmers' dependence on rain-fed agriculture and increase overall household food security and income. Dependence on rain-fed agriculture often leads to varied yields, crop failures and the risks of food insecurity, while studies have shown that rain-fed agriculture combined with conservation agriculture techniques can increase crop yields by storing water in the soil more effectively. A range of irrigation technologies and methods have been adopted in African drylands, including water abstraction with gravity or mobile pumping schemes, canal or pipe conveyance systems, and furrow irrigation, depending on the biophysical, geographic, topographic and socio-economic conditions on the ground. Some schemes are led by government or supported by NGOs in partnership with farmers' cooperatives or water users' associations, while others are managed by out-growers or private entrepreneurs. Potential for small-scale irrigation development in drylands should be further tapped in Africa utilizing low-cost, locally applied technologies (Tafesse, 2003).

It should also be recognized, however, that there are limitations to the potential for irrigation in Africa. Many households do not have direct access to adequate irrigation water, and would have to depend on water harvesting and storage, perhaps supplemented by irrigation. The practical limitations of water storage imply that in many cases small-scale irrigation could be applied only to small areas, and would logically be used for high-value rather than basic food crops. However this would require highly intensive agriculture accompanied by a good marketing scheme. This is a reminder that climate change adaptation strategies will not always be able to prescribe only simple solutions. In this case small-scale irrigation will be most effective where a vibrant market exists for a high-value crop, and an adaptation strategy would need to take all of this into account.

Market-based options

Climate change is likely to reduce opportunities for traditional agro-based economic activities in parts of the semi-arid tropics. **Ecotourism** may offer an alternative income source. When properly conducted, eco-tourism helps educate the traveller; provides funds for conservation; directly benefits the economic development and political empowerment of local communities; and fosters respect for different cultures and human rights all in a sustainable manner (Honey, 2008; The Nature Conservancy, 2009).

Many semi-arid areas in Africa (and some arid zones) are rich in wildlife. While wildlife and livestock might face the same threats from climate change, it is very likely that wildlife habitats will demonstrate considerable resilience. **Wildlife tourism** may well provide a valuable alternative livelihood, and there is considerable evidence that cattle can be mixed with various types of wildlife species to provide multiple benefits (Western et al., 1994).

However, production in the Semi Arid Tropics (SAT) could potentially at least be doubled, even in the face of climate change. A much more important aspect of market-based options is market access which is currently poor in the SAT. Improved market access would provide far greater income opportunities and livelihood resilience to farmers which would greatly mitigate the impacts of climate change (IAASTD, 2009).

Institutional options

Early warning systems and improved climate information can help farmers to take appropriate actions in a timely manner depending on expected weather conditions. For example early maturing varieties of maize can be planted when rains are expected to start late. With the addition of early warning systems, livestock rearing and farming can be aided by the use of models, satellite imagery, and better forecasts (UNIEWP, 2007).

Agriculture in the semi-arid drylands can often suffer from severe year-to-year variability, just as pastoralism does in arid zones. An emergency response capacity will be needed to cope with bad years in all drylands zones. Food aid is currently widely used to bring relief to starving populations. However, food relief is generally designed to be responsive – to be mobilized according to immediate need. An effective adaptation strategy should seek to help people cope with bad years. This should act as insurance that prevents the damage done in bad years from eliminating the gains made in better years. This would involve the development of a security strategy based on either the availability of food stocks or cash reserves. In recent years a number of donors have begun to shift their aid from food aid to cash aid, often targeting women and children for cash relief. A comprehensive emergency response capacity would also provide reserves of fodder and seed banks for cereals and legumes (GL-CRSP, 2004). Such strategies would be expensive, and would often require continued donor support. However, if applied effectively, they can mitigate the arrested development of poor years and eliminate costly food aid.

In addition to conventional approaches to emergency relief, **market-based risk management mechanisms** such as insurance-related instruments that spread and pool risks are promising ways of achieving risk reduction, providing compensation for, and adaptation to, climate-related and other disasters in developing countries.

Index-based insurance also has substantial promise. Over the past year, the International Livestock Research Institute and its partners have pursued a substantial research and development program aimed at designing, developing and implementing market-mediated index-based livestock insurance products to protect pastoralists from drought related livestock losses. The index in this case is pegged on readily-available satellite readings of forage availability which has demonstrated a statistically high correlation with livestock mortality in the coverage area. Engagement with the target clientele has revealed substantial interest and a willingness to pay that indicates strong commercial potential (personal communication (Mude et al., 2009)

Dry sub-humid zone

The dry sub-humid zone consists of savanna-type vegetation that receives 1000–1500 mm rainfall/year and has a growing period of 6–9 months. The predominant livelihood is smallholder rain-fed agriculture, mainly for subsistence. Crops grown include, among others, maize, millet, sorghum, cassava, yam, groundnut, cowpeas and leguminous forages. There is also some mixed crop–livestock farming. While this zone's high arable potential is exploited primarily for food crop production, sedentary livestock and dairy production are becoming increasingly viable options.

Like other dryland agro-ecological zones, climate-related uncertainty due to inter- and intra-seasonal rainfall variability is already a fundamental constraint to agricultural production in the dry sub-humid zone. Long-term climate change will very likely exacerbate the situation in many parts of the zone, with less predictable rain, reduced soil moisture, increased heat stress, floods as well as changing pests, diseases and weeds.

The following are some recommendations for NRM-based climate change adaptation activities that should be considered in the dry sub-humid zone. Market-based and institutional measures are not presented in this section as both semi-arid and dry sub-humid zones practise agro-based livelihood activities to varied degrees and thus share many adaptation options in these areas.

Dry sub-humid zone adaptation options

NRM-based options

With the addition of early warning systems, livestock rearing and farming can be aided by the use of models, satellite imagery, and better forecasts (UNIEWP, 2007). 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). The use of an integrated approach combining trees and shrubs with crops and/or livestock should be

considered as an adaptive response to climate change. Agroforestry is an attractive adaptation strategy for a number of reasons. First, woody perennials are able to explore a larger soil volume for water and nutrients, provide better soil cover and reduce surface runoff, all of which will reduce the impacts of droughts and extreme rainfall. Second, woody perennials can help to build soil carbon which in turn can increase water and nutrient use efficiency. Third, tree-based agricultural systems often provide additional benefits such as fruits, fodder, fuelwood and timber and thereby diversifies the production system to buffer against weather related production losses and hence raise smallholder resilience against climate impacts (Nair et al. 2009).

Box 2: Weather Insurance

In 2006, the World Food Programme (WFP) partnered with French insurance firm Axa Re to pilot a programme to provide cash payouts to farmers in the event of a severe drought in Ethiopia. Now they are working with the Ethiopian government to expand the programme for three years, starting 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.

In another example from the World Bank Commodity Risk Management Group (CRMG), Malawi has introduced an innovative pilot drought insurance programme for local groundnut farmers, to help them mitigate the risks associated with periodic droughts. The insurance supports farmers especially to obtain the financing necessary to purchase certified seeds, which have greater resistance to disease and produce increased yields and revenues. The programme is currently being implemented on a pilot basis involving nearly 900 farmers in four areas and, if successful, can be scaled up to other crops, other areas in Malawi and other countries in 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 ensure sustainability and scalability of the programme.

3.

Carbon in the African drylands

Plants take up carbon dioxide from the atmosphere and incorporate it into plant biomass through photosynthesis. Some of this carbon is emitted back to the atmosphere but what is left – the live and the dead plant parts, above and below ground – make up an organic carbon reservoir. Some of the dead plant matter is incorporated into the soil in humus, thereby enhancing the soil organic carbon pool.

Plant biomass per unit area of drylands is low (about 6 kilograms per square metre) compared with many terrestrial ecosystems (about 10–18 kilograms). But the large surface area of drylands gives dryland carbon sequestration a global significance. In particular, total dryland soil organic carbon reserves comprise 27 per cent of the global soil organic carbon reserves (MA, 2005). Soil properties, such as the chemical composition of soil organic matter and the matrix in which it is held, determine the different capacities of the land to act as a store for carbon, which has direct implications for capturing greenhouse gases (FAO, 2004). The fact that many of the dryland soils have been degraded means that they are currently far from saturated with carbon and their potential to sequester carbon may be very high (Farage et al., 2003). Furthermore, although growth potential is ultimately rainfall limited, plant growth in drylands is in practice often nutrient-limited (van Keulen and Breman, 1990), so that there is opportunity for increasing biomass productivity through improved nutrient management even in below average rainfall season.

Land degradation and carbon emissions

Despite the mounting global concerns aroused by the observed impacts of desertification, the available data on the extent of land degradation in drylands are extremely limited. This is partly due to the diversity in methodological approaches and underlying assumptions used by the different analyses as well as the high variability of year-to-year drylands ecosystem conditions (MA, 2005). In the early 1990s, the Global Assessment of Soil Degradation, based on expert opinion, estimated that 20 per cent of drylands (excluding hyper-arid areas) were affected by soil degradation to different degrees (Oldman et al., 1991). Meanwhile, Dregne and Chou (1992) stated that approximately 70 per cent of the drylands (excluding hyper-arid areas) are degraded, due to a combination of natural and human-caused stresses. Another partial-coverage estimate based on regional data sets derived from literature reviews, erosion models, field assessments and remote sensing conducted in 2003 concluded that the main areas of degradation were estimated to cover 10 per cent of global drylands (including hyper-arid drylands). Building on these results, the Millenium Ecosystems Assessment report (MA, 2005) estimates that the true level of degradation lies somewhere between the 10 and 20 percent figures. The Land Degradation Assessment in Drylands (LADA) project, funded by the Global Environmental Facility (GEF) through UNEP and carried out by the FAO is drawing together information about degradation and developing methodologies of assessing the extent of land degradation and its impacts.

Land use change and degradation are important sources of greenhouse gases globally, responsible for about 20 per cent of emissions (IPCC, 2007b). Land degradation leads to increased carbon emissions both through loss of biomass when vegetation is destroyed and through increased soil erosion. Erosion leads to emissions in two ways: by reducing primary productivity, thereby reducing soils' potential to store carbon, and through direct losses of stored organic matter. Although not all carbon in eroded soil is returned to the atmosphere immediately, the net effect of erosion is likely to be increased carbon emissions (MA, 2005).

There have been a number of estimates of the rate of carbon emissions due to land degradation in drylands at different scales. At the global scale, Lal (2001) estimated that dryland ecosystems contribute 0.23 – 0.29 Giga ton (Gt) of carbon a year to the atmosphere, which is about 4% of global emissions from all sources combined (MA, 2005). At country level, estimates show, for example in China, that degradation of grassland, particularly on the Qinghai-Tibetan Plateau, has led to the loss of 3.56 Gt soil organic carbon over the last 20 years. It is estimated that the soils of China overall now act as a net carbon source, with a loss of 2.86 Gt in the same period (Xie, et al., 2007, (Xu et al., 2004; (ESPA) China, 2008).

Grace et al. (2006) reviewed carbon fluxes in tropical savannas. They found that carbon sequestration rates in these ecosystems average 0.14 to 0.39 tonnes carbon per hectare per year. They concluded that "if savannas were to be protected from fire and over-grazing, most of them would accumulate substantial carbon and the sink would be larger. Savannas are under anthropogenic pressure, but this has been much less publicized than deforestation in the rain forest biome. The rate of loss is not well established but may exceed 1 per cent per year, approximately twice as fast as that of rain forests. Globally, this is likely to constitute a flux to the atmosphere that is at least as large as that arising from deforestation of the rain forest."

This shows, therefore, how vital it is from a climate perspective that african grasslands and savannahs are managed to enhance carbon sequestration and that further studies are clearly required in this area.

As well as contributing to greenhouse gas emissions, drylands are themselves vulnerable to the effects of climate change and the impacts of climate change in these areas may lead in turn to further carbon emissions. Any further failure of plant growth due to increased temperatures would further reduce carbon inputs to the soil, accelerating its degradation. Smith et al. (2008) point out that "even partial loss of vegetation integrity could make soils more vulnerable to degradation through other agents such as over-grazing and cultivation."

The map (Figure 1) shows how the density of carbon stored, that is, the mass of carbon per hectare, varies throughout drylands [4]

[4] The carbon densities are derived from two global datasets: the carbon stock in biomass is from a map based on the IPCC Tier-1 Methodology using global land cover data. (Ruesch and Gibbs, in review); soil carbon is from the Global Soil Data Products CD-ROM (International Geosphere-Biosphere Programme-Data and Information System, 2000). The delineation of drylands is from UNEP World Conservation Monitoring Centre's (WCMC) map of areas of relevance to the CBD's programme of work on dry and sub-humid lands (UNEP-WCMC, 2007).

Figure1. Global carbon stock density in drylands (above and below ground biomass plus soil carbon)

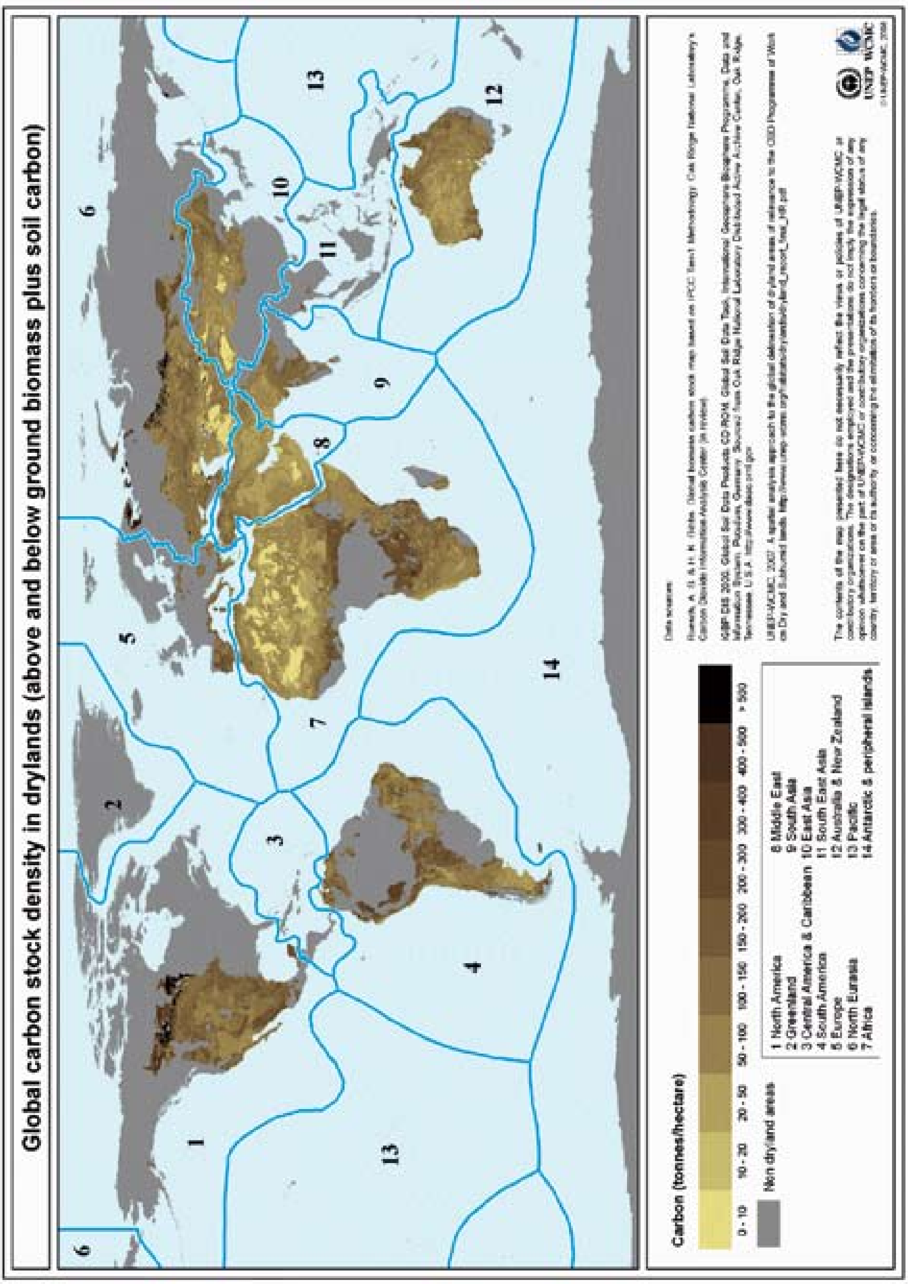

Table 2 gives a breakdown of the carbon stored in each region in drylands. Figures for the total carbon stock in each region are from Campbell et al. (2008) and are derived from the same data as the dryland figures. Estimates of carbon stored in each region are sensitive to changes in land cover type. Therefore for detailed regional or national purposes, it will be necessary to refine global land cover data with more detailed local data. Nevertheless, this global overview shows that dryland carbon storage accounts for more than one third of the global stock. In some regions, such as the Middle East and Africa, a very high proportion of carbon is in drylands, so any sequestration measures there would need to address dryland ecosystems. It is noticeable that despite the presence of important forest sinks in parts of Africa, fully 59 per cent of Africa's carbon stocks are found in the dry regions.[5]

Table 2. Comparison of total and drylands carbon stocks in regions of the world

Map number	Region	Total carbon stock per region (Gt)	Carbon stock in drylands (Gt)	Share of regional carbon stock held in drylands (%)
1.	North America	388	121	31
2.	Greenland	5	0	0
3.	Central America & Caribbean	16	1	7
4.	South America	341	115	34
5.	Europe	100	18	18
6.	North Eurasia	404	96	24
7.	Africa	356	211	59
8.	Middle East	44	41	94
9.	South Asia	54	26	49
10.	East Asia	124	41	33
11.	South East Asia	132	3	2
12.	Australia/New Zealand	85	68	80
13.	Pacific	3	0	0
Total		**2053**	**743**	**36**

Source: Campbell et al. (2008)

[5] See footnote 2

Estimates of dryland carbon sequestration potential

Several studies have attempted to assess the potential for carbon sequestration in drylands. Considering all drylands ecosystems, Lal (2001) estimated that they had the potential to sequester up to 0.4–0.6 Gt of carbon a year if eroded and degraded dryland soils were restored and their further degradation were stopped. In addition, he suggested that various active ecosystem management techniques, such as reclamation of saline soils, could increase carbon sequestration by 0.5–1.3 Gt of carbon a year. Squires et al. (1995) estimated similar figures. Keller and Goldstein (1998) reached the slightly higher figure of 0.8 Gt of carbon per year using estimates of areas of land suitable for restoration in woodlands, grasslands, and deserts, combined with estimates of the rate at which restoration can proceed.

Other studies have examined specific ecosystems in particular locations. For example, Glenday (2008) measured forest carbon densities of 58 to 94 tonnes carbon/ha in the dry Arabuko–Sokoke Forest in Kenya and concluded that improved management of wood harvesting and forest rehabilitation could substantially increase terrestrial carbon sequestration. Farage et al. (2007) used soil organic matter models to explore the effects of modifying agricultural practices to increase soil carbon stocks in dryland farming systems in Nigeria, Sudan and Argentina. Modelling showed that it would be possible to change current farming systems to convert these soils from carbon sources to net sinks without increasing farmers' energy demand. The models indicated that annual rates of carbon sequestration of 0.08-0.17 tonnes per ha per year averaged over the next 50 years could be obtained.

Despite these studies, significant gaps in knowledge remain. Better information is needed on the impact of land use changes and desertification on carbon sequestration and the cost-benefit ratio of soil improvement and carbon sequestration practices for small landholders and subsistence farmers in dryland ecosystems (MA, 2005).

Climate change mitigation through addressing desertification, land degradation and drought (DLDD)

Addressing land degradation in dryland ecosystems presents two complementary ways of mitigating climate change. First, by slowing or halting degradation, associated emissions can be similarly reduced. Second, and arguably of greater significance, changes in land management practices can lead to greater carbon sequestration, that is, to removing carbon from the atmosphere. In general, on per unit area basis, the carbon storage potential of dryland ecosystems is lower than for moist tropical systems, but the large area of drylands means that overall they have significant scope for sequestration.

Managing drylands for carbon sequestration

Since carbon losses from drylands are associated with loss of vegetation cover and soil erosion, management interventions that slow or reverse these processes can simultaneously achieve carbon sequestration. There is a wide range of strategies to increase the stock of carbon in the soil. Examples include enhancing soil quality, erosion control, afforestation and woodland regeneration, no-till farming, cover crops, nutrient management, manuring and sludge application, grazing management strategies, water conservation and harvesting, efficient irrigation, land-use change (crops to grass/ trees), fallow, agroforestry, and the use of legumes (FAO, 2004; Lal, 2004; Smith, 2008).

There is a growing interest in assessing the carbon sequestration potential of such strategies quantitatively. Using a modelling approach, Farage et al. (2007) found the most effective practices for increasing soil carbon storage were those that maximised the input of organic matter, particularly farmyard manure (up to 0.09 tonnes carbon per hectare per year), maintaining trees (up to 0.15 tonnes carbon per hectare per year) and adopting zero tillage (up to 0.04 tonnes carbon per hectare per year).

Tiessen et al. (1998) reviewed data on carbon and biomass budgets under different land uses in tropical savannas and some dry forests in West Africa and North-eastern Brazil. They found that improvements in carbon sequestration in these semi-arid regions depended on an increase in crop production under suitable rotations, improved fallow and animal husbandry, and a limitation on biomass burning. Use of fertilizer was required for improved productivity but socio-economic constraints largely prevented such improvements, resulting in a very limited scope for changes in soil carbon management.

Increasing the tree component in agricultural and pastoral systems will sequester atmospheric carbon in the plant biomass and in the soil, thereby mitigating climate change. The technical potential has been estimated to lie in the range of 600 Mt C per year until 2040 (Verchot et al., 2007).

Increasing carbon stocks in the soil increases soil fertility, workability and water holding capacity, and reduces erosion risk and can thus reduce the vulnerability of managed soils to future global warming (Smith, 2008) as well as improving productivity and securing ecosystem services, functions and resilience. However, hidden costs also need to be considered, such as the addition of mineral or organic fertilizer (especially nitrogen and phosphorus) and water, which would need significant capital investment and concerted efforts in improved management practices (MA, 2005).

According to Lal (2009), despite its numerous direct and ancillary benefits, enhancing the soil organic matter (SOM) pool is a major challenge, especially in impoverished and depleted soils in harsh tropical climates. In addition to biophysical factors, there are also numerous social, economic and political constraints that limit increase in SOM pools. Conversion of plough-tillage to no-till farming, an important practice to enhance the SOM pool, is constrained by the limited access to herbicides and seed drill, and the competing uses of crop residues. Yet, enhancing the SOM pool is essential to restoring degraded soils, advancing food security and improving the environment. Important subjects among researchable topics include:

a. Assessing the rate of SOM accretion for a wide range of land use and management practices with reference to a baseline;
b. Evaluating the importance of biochar;
c. Measuring and predicting SOM at landscape and extrapolation to regional scale;
d. Establishing relationships between SOM and soil quality and agronomic productivity;
e. Determining on- and off-site effects of crop residues removal for ethanol/biofuel production;
f. Determining the fate of carbon in SOM translocated by erosional processes;
g. Evaluating nutrient requirements for increasing SOM in croplands;
h. Validating predictive models in tropical environments; and
i. Developing methodology for trading carbon credits.

Linking drylands management to carbon markets

Carbon markets and their current limitations

Carbon markets trade carbon credits, which are bought by governments seeking to meet emissions reduction targets under the Kyoto Protocol, and also by companies subject to emissions regulation. There are three main carbon markets:

a. The Kyoto compliance market, which includes the Clean Development Mechanisms (CDM);
b. Other compliance or pre-compliance markets, such as emissions trading platforms created by state-level legislation in Australia and the USA; and
c. A voluntary carbon market, which mainly trades in emissions reductions that cannot be traded in the compliance markets. At present dryland management activities (except afforestation and reforestation) are not eligible under the CDM and most pre-compliance systems.

Currently, the only purchasers of dryland carbon credits are in the voluntary market, which comprises a very small proportion of the total market.

Under the current carbon trading regime, unless dryland carbon credits can be used to meet compliance targets, demand will remain limited. There are no agreed standards and methodologies for delivering certified emissions reductions from dryland management activities. There is some interest in land use derived carbon credits among private companies and carbon funds, driven partly by expectations that these carbon assets may fetch a premium price in the future. The main current constraints on the entry of land use emissions reductions into compliance markets are the risks that land use-based carbon sequestration may not be permanent and methodological challenges.

Forests are receiving more attention than other ecosystems in mitigation negotiations. The United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (UN-REDD Programme) is aimed at "tipping the economic balance in favour of sustainable management of forests so that their formidable economic, environmental and social goods and services benefit countries, communities and forest users while also contributing to important reductions in greenhouse gas emissions". The UN-REDD Programme has nine initial pilot sites, two of which – Tanzania and Zambia – are dryland woodland countries. Tropical dry forests can store significant amounts of carbon (Edinburgh Centre for Carbon Management, 2007) so UN-REDD may be a suitable finance mechanism for anti-degradation measures in these ecosystems.

The price of carbon strongly influences whether interventions to manage land degradation and sequester carbon are cost effective. At present, the price of soil organic carbon, for example, is low, about $1 per tonne, so only low-cost interventions are likely to be cost-effective for land managers. Smith et al. (2008) concluded that there was technically the potential to increase soil organic carbon stocks by about 1–1.3 Gt per year[6]. However, he found that if carbon prices were less than US$20 per tonne it would only be economically feasible to increase soil carbon stocks by up to 0.4 Gt per year. At higher carbon prices, costlier interventions may generate sufficient revenue through carbon credits to be worth undertaking.

The important questions for drylands, then, are first to identify areas – forest or other – where the carbon storage potential is great enough to attract carbon finance based on the current carbon price; and second to consider whether UN-REDD and other mechanisms could prioritize schemes that also deliver co-benefits such as watershed protection.

Criteria for carbon finance projects

Carbon markets are likely to develop more rapidly and with greater financial backing than other markets for ecosystem services, and it is important that drylands projects are included. Projects must meet basic criteria, including solid scientific documentation of the carbon sequestration impacts of management practices; and adoption of these practices must be in line with national sustainable development priorities and adaptation plans.

[6] This figure refers to organic carbon in general and is not specific to drylands.

Basic requirements for carbon finance projects are:

1. Robust and transparent institutional arrangements, including a clear owner, a developer of the carbon assets, a standard recognized by the buyer and a third party verifier accredited by the standard. Projects must contribute to sustainable development of the host country.
2. An approved methodology detailing the baseline of CO2 emissions and a carbon monitoring approach.
3. A Project Design Document detailing:
   a. A baseline description to demonstrate the business-as-usual situation and the with-project scenario;
   b. Justification of additionality to demonstrate that the project can only be implemented because of the carbon finance component;
   c. A leakage assessment to avoid the project resulting in extra carbon emissions outside the project area;
   d. A permanence or reversibility assessment to avoid the emission of sequestered carbon; and
   e. A carbon monitoring plan detailing the monitoring design and intervals.

Unfortunately, the processes of the CDM have proved to be either excessively complicated, or not suited to African needs, or both. For example, there are 1,900 registered projects globally. Of these, only 35 (1.84 per cent) are hosted in Africa and concentrated in a few countries: 17 in South Africa, 5 in Morocco, 4 in Egypt, 3 in Nigeria, 2 in Tunisia, 2 in Uganda, 1 in Cote d'Ivoire and 1 in Kenya[7]. Further, so far, only 0.43 per cent of CDM projects are related to afforestation/reforestation. This means that only 8 projects have been approved worldwide, indicating the limited applicability of the current CDM for forest-based carbon projects.[8]

[7] (http://cdm.unfccc.int/Statistics/Registration/NumOfRegisteredProjByHostPartiesPieChart.html)
[8] (http://cdm.unfccc.int/Statistics/Registration/RegisteredProjByScopePieChart.html)

Support for drylands inhabitants

Section 2 of this publication clearly shows that there are many options for ensuring adaptation to climate change in the drylands. In almost all cases, they will lead to better land management, better conservation of existing soil carbon and greater carbon sequestration. However, current management practices do not directly aim to maximize carbon, and future adaptation programmes will have to be designed with carbon conservation and sequestration as a specific objective if there is to be any possibility of benefitting from carbon markets. Technical support for, and promotion of, sustainable drylands management practices that sequester carbon will be needed. For effective projects and meaningful results, households will need to aggregate their carbon assets. Herders' associations or other NGOs could play an important role in both of these areas.

Carbon finance projects require a clear project boundary, clear tenure rights in national law (whether private or communal), and that rangeland owners can effectively exclude others from use. These are clearly a challenge for pastoralists who generally have weak tenure rights. However, demonstrated potential for producing carbon finance flows may aid pastoralists in lobbying for their land use rights to be recognized.

Many organizations working with pastoral people have strong capacities for promoting the adoption of carbon sequestrating management practices, but several constraints have been identified as preventing them from attracting carbon finance. At international and national levels, there is often insufficient awareness and understanding of the mitigation potential of rangelands. Among potential project developers, there is limited understanding of market opportunities. The costs of developing early pioneer projects and methodologies are also high.

Strengthening local level institutional management

Local level institutions influence the livelihoods and adaptation of rural households as they structure the distribution of climate risk impacts. It essential that in the development of adaptation and mitigation strategies community level institutions be strengthened, especially given that that benefits of climate change adaptation and mitigation may differ across households and communities with different equity and distributional implications. Such institutions also determine the incentive structures for household and community level adaptation responses and which shape the nature of these responses. Further, local management institutions mediate external interventions into local contexts, and articulate between local and extra-local social and political processes through which adaptation efforts unfold (Agrawal, 2008).

Diversification of livelihoods (e.g. more skills, education) and assets (e.g. better soil health and water retention capacity) are important adaptive strategies to climate change variability. Adaptive strategies to cope with climate change that has taken place (such as crop varieties that do better in drought conditions) are also important. The issue of effective institutions for realizing effective adaptation or mitigation responses is a major issue in moving forward on all these fronts. It would be important for projects and governments contemplating application of any potential options or opportunities that they pay due attention to working out the institutional issues.

Blending sources of support: the need for innovative thinking

It can be argued that the current carbon finance regime is too complex for application in the drylands of Africa. The very specific needs of carbon markets are difficult to achieve in the drylands. These include clear project boundaries, the need for carbon gains to be monitorable, verifiable and reportable, the need for certainty of permanence of carbon and lack of leakage. Drylands carbon is so widely and thinly spread that its ownership is difficult to define and compensating the thousands of people responsible for managing it is a challenge. We should therefore avoid any precipitate approach to linking drylands to carbon markets without taking this into consideration. Given today's focus on climate change, it is easy to forget that the people of Africa's drylands are among the world's poorest and merit continued support for their efforts to escape from poverty irrespective of opportunities for finance through carbon markets. However, the people of Africa's drylands will be victims of climate change, and certainly deserve to be compensated for their role in managing a significant portion of the earth's carbon stocks.

We therefore need to work towards a financing package for Africa's drylands that fights poverty, funds adaptation and rewards carbon management. We suggest that it is time for the international community to consider a compact between donors and the inhabitants of the drylands in which 'conventional' overseas development assistance increases and continues to play its important poverty-alleviation role, where adaptation funds flow to the poorest, and where carbon finance rewards the millions of people involved in drylands land management. Whether a CDM modified to take into consideration land use, land use change and forestry might work in the drylands, or whether an extended UN-REDD Programme might be effective, both need to be investigated. Alternatively, we may need a very different instrument that rewards nations and communities for the successful implementation of land management programmes at national and landscape levels. It is important to recognize that adaptation and mitigation issues and challenges in African drylands are closely linked and support for these synergies will need to be promoted in the development desertification and SLM of funding mechanisms.

4. Conclusions

The drylands of Africa face major challenges in the years ahead, with land degradation and climate change heading the list. Their inhabitants face corresponding challenges that threaten their livelihoods. Adaptation strategies are available that can help people and communities cope with these challenges; and if these strategies can be integrated with mitigation efforts, incentives and support can be mainstreamed into developing resilient and sustainable land management systems.

Drylands livelihood systems are inherently opportunistic, and adaptation measures outlined in this paper are largely familiar to pastoralists and other inhabitants. Their effectiveness will however depend on careful selection, an integrated approach and longer planning timeframes, together with an enabling policy environment that reinforces actions at local and higher scales.

Many of these sustainable land management practices also have significant carbon sequestration potential, particularly where they increase the organic carbon content of soils. As Lal (2004) pointed out, the carbon sink capacity of tropical dryland soils is high in part because they have already lost a lot of carbon. Restoring that carbon offers long-term sequestration and can improve crop yields and increase ecosystems' resilience to future climate variability.

The UNCCD's 10-year strategic plan (up to 2018) recognizes the links between land degradation and climate change. This is shown, for example by an Indicator under Strategic Objective 3, which aims to achieve an "increase in carbon stocks (soil and plant biomass) in affected areas".

However, weak institutions, limited infrastructure and resource-poor agricultural systems often limit capacity to address soil carbon and land degradation. Carbon markets offer a possible way of financing measures to do so in some areas. However, for significant carbon finance to be channelled to dryland ecosystems, it may be necessary for market mechanisms to prioritize or allow a premium for schemes that offer other benefits. Both forest and non-forest ecosystems have carbon sequestration potential, but the price of carbon traded in the voluntary market is often too low to influence land management practices at present. In addition, cost-effective systems that can measure and monitor carbon over large areas will be required to enable such schemes to operate in drylands.

Carbon market is a market and pastoralists, as any other politically weak groups, have always had difficulties coping with market. Thus, while carbon markets are an option to improve conditions in drylands, a number of conditions will need to be recognized and promoted such as simplification of processes, capacity building, political will to help relatively weaker groups.

Drylands livelihoods are complex, drylands ecosystems are fragile, and despite the relatively high potential of the drylands, poor people struggle to escape poverty. No single intervention can resolve the challenges of drylands. There is a need for continuing and increasing ODA for poverty reduction. There will be a growing need for adaptation funding to help people cope with the effects of climate change. There is a huge opportunity to protect the carbon in the drylands and to sequester more. This will require innovative and new schemes to stimulate improved land management. The information in this publication, and other abundant evidence, demonstrate the need for the International Community to come together to provide and sequence various sources of funding to stimulate development in the drylands and to protect an important stock of global carbon.

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