Review of evidence on drylands pastoral systems and climate change

Implications and opportunities for mitigation and adaptation

LAND AND WATER DISCUSSION PAPER

8

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List of Acronyms

C	Carbon
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
DfID	Department for International Development (UK)
FAO	Food and Agriculture Organization of the United Nations
GEF	Global Environment Facility
GHG	Greenhouse gases
GIS	Geographic information system
GLADA	Global Assessment of Land Degradation and Improvement
GM	Global Mechanism
GCWG	Grasslands Carbon Working Group
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
MDG	Millennium Development Goal
NAPA	National Adaptation Programmes of Action (of UNFCCC)
NGO	Non-governmental Organization
N	Nitrogen
N_2O	Nitrous oxide
NVDI	Normalized Difference Vegetation Index
SIC	Soil Inorganic Carbon
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
SSA	Sub-Saharan Africa
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNCBD	UN Convention on Biological Diversity
UNCCD	UN Convention to Combat Desertification
UNCSD	UN Commission on Sustainable Development
UNFCCC	UN Framework Convention on Climate Change
WHO	World Health Organization

Abstract

In light of global concerns over the impacts of climate change and climate variability, this document provides an overview of opportunities for adaptation and mitigation in dryland pastoral and agropastoral systems. It makes a case for a concerted global effort to promote mitigation practices that also have benefits for adaptation and livelihoods of pastoralists and agropastoralists in drylands.

This review first highlights the importance of drylands, grazing lands and livestock-based livelihoods and illustrates the interrelations between climate change, land and livestock. It then provides estimates of the potential carbon storage and sequestration in pasture and rangelands in drylands and outlines the main land management measures for improving carbon cycling and grassland management. The socio-economic dimensions of rangeland management and the climate change adaptation and associated co-benefits are then highlighted. In conclusion, it presents some key messages on the importance of grasslands and rangelands in terms of their contribution to carbon sequestration and to the livelihoods of the poor. It highlights the fact that management strategies and practices that contribute to mitigating climate change will also play a major role in climate change adaptation and reducing vulnerability to natural disasters for the millions of people – including the poor – who depend on these land-use systems. Finally, it provides some suggestions on ways forward in light of the current policy framework and climate change negotiations.

The review also highlights the vast untapped potential for climate change mitigation and adaptation associated with improved carbon sequestration in pastoral systems and rangelands. Much of this potential lies in soil carbon sequestration. Its neglect during the Kyoto process[1] stemmed from concerns regarding perceived difficulties of measurement and monitoring due to soil spatial variability, and of ensuring permanence (IPCC, 2008). Recent negotiations have highlighted the potential for Reducing Emissions from Deforestation and Forest Degradation (REDD) and for carbon sequestration in soils and above-ground biomass in other lands besides forests. Evidence regarding the potential for carbon sequestration in rangelands and grasslands is continually accumulating. The review demonstrates that there is a strong justification for a concerted international process to explore and support efforts for achieving carbon sequestration and promoting sustainable (agro)-pastoral livelihoods in dryland systems through the ongoing post-Kyoto deliberations and negotiations.

[1] The Kyoto Protocol, adopted in February 1995 under the UNFCCC, imposes limits on emissions of carbon dioxide and other greenhouse gases that contribute to rising world temperatures, melting glaciers and rising oceans. The Clean Development Mechanism (CDM), a major carbon offsetting system under the Kyoto Protocol, aims to lower industrialized countries' costs of cutting greenhouse gas emissions by allowing them to purchase "emission credits" that subsidize supposedly low–carbon "sustainable development" projects in developing countries. Among other sources of emission credit, these mechanisms recognized afforestation and reforestation as effective and readily measurable means to sequester carbon and reduce GHG emissions.

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The work is largely based on a state-of-the-art literature review and entirely the responsibility of the authors. The authors see this as an evolving document covering a dynamic and increasingly critical topic, and welcome input and feedback from readers for future updating of the document in the light of further knowledge.

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Executive Summary

Climate change and variability are long-term environmental issues and pose serious threats to vulnerable and impoverished people worldwide. In this context, governments, the scientific community, development organizations and the private sector increasingly recognize that drylands, grasslands and rangelands deserve greater attention, not only for their large extent, widespread degradation and limited resilience to drought and desertification, but also for their potential capacity to sequester and store carbon in soils while supporting sustainable pastoral and agropastoral livelihoods for millions of people. Soils represent the earth's largest carbon sink that can be controlled and improved – larger even than forests. In addition, grassland management has been cited as the second most important agricultural technology available for climate change mitigation.

This review argues that livestock and pastoral systems have a major role to play in climate change mitigation and, importantly, in supporting adaptation and reducing vulnerability. Pastoral systems occupy two thirds of global dryland areas, host a large share of the world's poor and have a higher rate of desertification than other land uses. Livestock production is also a growing sector. It is estimated that 1 billion people depend on livestock, and livestock serves as at least a partial source of income and food security for 70 percent of the world's 880 million rural poor who live on less than USD 1.00 per day.

Degradation of the land base negatively affects the accumulation of carbon in the soils. Thus, reversing land degradation in extensive dryland areas through improved pasture and rangeland management would contribute to restoring the soil carbon sink while also improving livestock-based livelihoods.

The review also highlights the potential for soil carbon sequestration in dryland grazing areas and the multiple benefits of enhancing ecosystem services and processes for improving livelihoods while contributing to adaptation to climate change impacts. Realizing this potential will require increased awareness and coordinated global efforts. Arrangements to bring about climate change mitigation in drylands that simultaneously contribute to climate change adaptation should be a key area of focus in post-Kyoto mechanisms. Such win-win arrangements that successfully achieve both mitigation and adaptation benefits need to be implemented alongside interventions that address associated socio-political and economic barriers, such as land tenure constraints and inadequate services for, and political marginalization of, pastoral and agropastoral communities.

In conclusion, the review finds that there is significant potential for mitigating climate change through improved management of grazing lands in drylands, and emphasizes the concurrent opportunity to enhance the livelihoods of pastoral and agropastoral peoples

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and their adaptation capacity. These opportunities can be realized only with targeted capacity building and effective incentives for improved management of these fragile ecosystems, backed up by pro-poor livestock policies, integrated processes that address natural and social dimensions, and funding mechanisms that enable multi-stakeholder engagement.

Importance of Drylands, Grazing Lands and Livestock Based Livelihoods

Grasslands cover approximately 30 percent of the earth's ice-free land surface and 70 percent its agricultural lands (FAO, 2005a; WRI, 2000; White, *et al*., 2000). Drylands occupy 41 percent of the its land area and are home to more than 2 billion people (UNEP, 2006). Of the 3.4 billion ha of rangelands worldwide, an estimated 73 percent are affected by soil degradation (WOCAT, 2009).

Over 1 billion people depend on livestock, and 70 percent of the 880 million rural poor living on less than USD 1.00 per day are at least partially dependent on livestock for their livelihoods (World Bank, 2007a; Livestock in Development, 1999). Livestock production can be found on two thirds of global drylands (Clay, 2004). Extensive pastoralism occurs on one fourth of the global land area and supports around 200 million pastoral households (Nori, *et al*., 2005). In Africa, 40 percent of the land is dedicated to pastoralism (IRIN, 2007) and 70 percent of the population relies on dry and subhumid lands for their daily livelihoods (CBD/UNEP/IUCN, 2007).

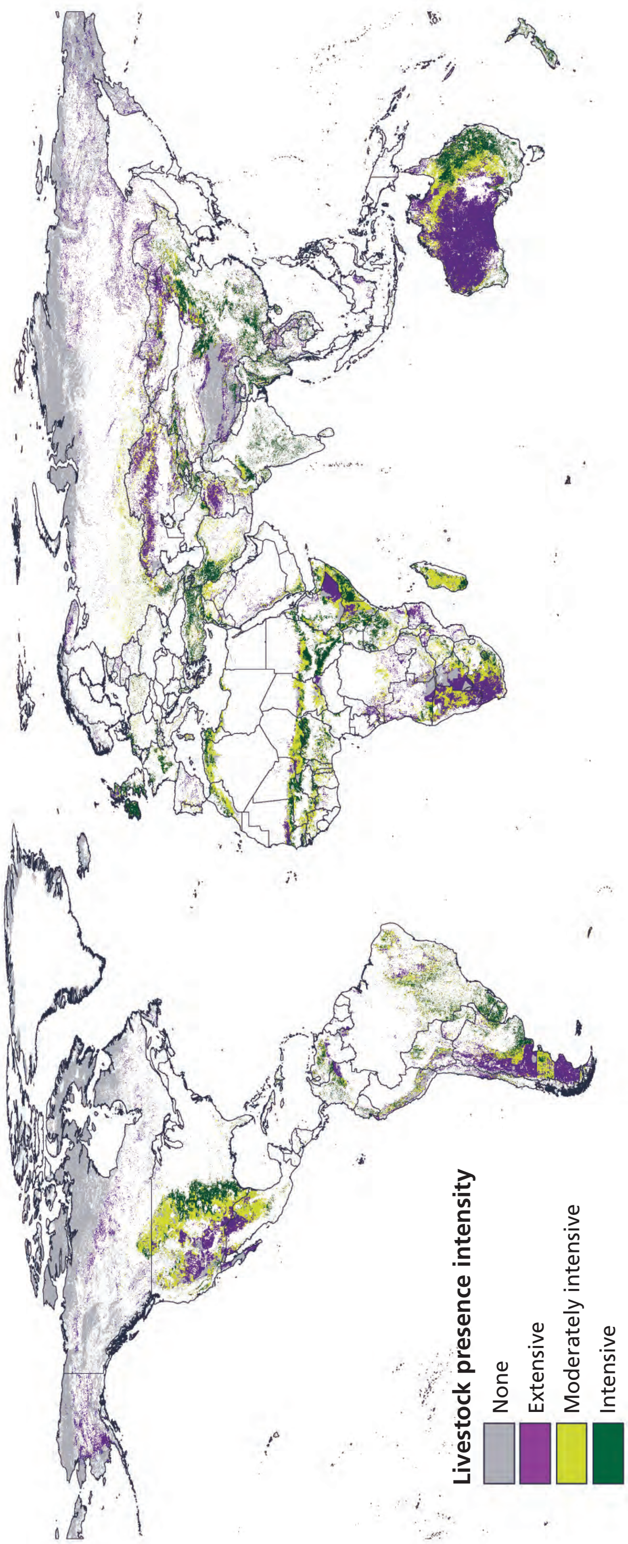
These drylands, which are predominantly used for livestock production, are particularly sensitive to land degradation, with 10–20 percent of drylands already degraded (Millennium Ecosystem Assessment, 2005). Some 23 percent of the world's poor (nearly 300 million people) are located in sub-Saharan Africa, and about 60 percent of these depend on livestock for some part of their livelihoods (Thornton, *et al*., 2002). In sub-Saharan Africa alone, 25 million pastoralists and 240 million agropastoralists depend on livestock as their primary source of income (IFPRI and ILRI, 2000). Figure 1 illustrates areas of extensive, moderately intensive and intensive pasture systems throughout the world.

Livestock products are the main outputs of grazing lands and continue to be the fastest growing agricultural subsector globally. In some developing countries, the livestock sector accounts for 50–80 percent of GDP (World Bank, 2007). Central and South America provide 39 percent of the world's meat production from grassland-based systems, and sub-Saharan Africa holds a 12.5 percent share – a large part of which originates from the drylands.

Livestock are socially and economically critical to rural livelihoods, thus high priority should be given to the sustainable management of the natural resources base that supports them. Grazing animals are the principal practical method of exploiting natural vegetation in dryland environments. Pastoralism is considered the most economically, culturally and socially appropriate strategy for maintaining the well-being of communities in dryland landscapes, because it is the only one that can simultaneously provide secure livelihoods, conserve ecosystem services, promote wildlife conservation and honour cultural values and traditions (ILRI 2006, UNDP 2006).

Rangelands are often and erroneously considered "marginal terrain", suitable only for low-intensity stock-rearing and hunting. In reality, dryland species and ecosystems have

FIGURE 1
Areas of extensive, moderately intensive and intensive pasture systems worldwide



Source: Nachtergaele and Petri, 2008.

PHOTO 1
The creation of protected areas and expansion of private game reserved has increased pressures on remaining pastures by the Maasai in Loliondo, Tanzania. "We have lived in harmony with wildlife for over a thousand years, now we are being forced to adopt unsustainable practices" a village leader said

PHOTO: DAVID BOERMA

developed unique mechanisms to cope with low and sporadic rainfall. They are highly resilient and recover quickly from common disturbances such as fire, herbivore pressure and drought. These attributes have great significance for the global system, especially in the context of climate change (Global Drylands Partnership, 2008). Moreover, rangelands are essential to the subsistence of pastoralists and agropastoralists, who usually constitute the most vulnerable groups in this land-use system.

Rangelands are estimated to store up to 30 percent of the world's soil carbon in addition to the substantial amount of above-ground carbon stored in trees, bushes, shrubs and grasses (White, *et al*., 2000; Grace, *et al*., 2006). In view of the vast extent of grasslands and rangelands and the degraded nature of large areas of these systems, the potential to sequester carbon through improved management is significant. Such management practices include restoring organic matter to soils, reducing erosion, and decreasing losses resulting from burning and overgrazing. The capacity to sequester carbon depends on the climatic zone, the past history and status of the land resources such as soil and vegetation, and the opportunities available to change management practices (management techniques, competition with other land uses, economic tradeoffs, land tenure, social organization, incentives and political will).

Climate Change, Land and Livestock Inter-relationships

Climate change caused a global average surface temperature increase of about 0.6°C during the twentieth century (IPCC, 2001), and current temperatures are predicted to increase further – between 1.4 and 5.8°C by 2100 – depending largely on the level of fossil-fuel combustion. Most of the observed increase in temperature will likely be due to the increase in anthropogenic greenhouse gas concentrations (IPCC, 2007). Besides a temperature increase of some 1 to 2.5°C by 2030, it is predicted that during this period, billions of people – particularly those in developing countries – will face changes in rainfall patterns and extreme events, such as severe water shortages, droughts or flooding. These events will increase the risk of land degradation and biodiversity loss. Climate change also will affect the length of growing seasons, and crop and livestock yields, and bring about increased risk of food shortages, insecurity, and pest and disease incidence, putting populations at greater health and livelihood risks.

Agriculture, which includes crop and livestock production, is responsible for some 14 percent of CO_2 equivalent emissions (IPPC 2007a), while land-use change including land degradation and deforestation (linked to agriculture) accounts for another 18 percent. Conversion of rangelands to cropland is a major cause of emissions, resulting in 95 percent loss of above-ground carbon and up to 60 percent loss of below-ground

PHOTO 2
Calves at pasture (Uganda)

carbon (Reid, *et al*., 2004; Guo and Gifford, 2000). Degradation of above-ground vegetation can cause an estimated loss of 6 tonnes of carbon per ha and soil degradation processes lead to a loss of 13 tonnes of carbon per ha (Woomer, *et al.*, 2004).

Although agriculture is viewed as a major source of GHG emissions, it holds great potential to contribute to mitigation, through actions to reduce greenhouse gas emissions (carbon dioxide, methane, nitrous oxide) and to enhance carbon sinks. Smith, *et al.* (2008) estimate that 89 percent of potential GHG emission reductions in global agriculture up to 2030 will be due to reductions in CO_2 emissions. Agriculture can also contribute to climate change adaptation through actions to reduce vulnerability of people and their ecosystems and improve capacities to cope with adverse impacts of climate change and natural disasters. This indicates the potential benefits of land-based mitigation measures in terms of adaptation and benefits for productivity and livelihoods. These co-benefits or 'win-win options' warrant greater attention than they have received to date.

The effects of climate change on productivity and carbon sequestration potential will depend significantly on location, management system and species. Global warming is expected to increase plant productivity in areas that will benefit from longer growing seasons and CO_2 fertilization (Cantagallo, *et al.*, 1997; Travasso, *et al.*, 1999). Temperature increases up to 3.0–3.5°C may increase productivity of crops, fodders and pastures (both C3[1] and C4[2] plant species). Increases in CO_2 levels also will have a positive impact on the productivity of C3 species. In semi-arid rangelands where shorter growing seasons are likely, rangeland productivity may decrease (Thornton, *et al*., 2008). Where reliable growing days drop below the days necessary for maize production in East and Southern Africa, livestock may become a more appropriate food and income source, especially for those farmers close to urban populations with higher demand for meat and dairy products (Thornton and Jones, 2009).

Global warming may accelerate decomposition of the carbon already stored in soils (Jenkinson, 1991; MacDonald, *et al.*, 1999; Niklinska, *et al.*, 1999; Scholtes, *et al.*, 1999). However, at the same time, the estimated magnitude of the fertilization effect (at current rates of increase of CO_2 in the atmosphere) is a net absorption of 0.036 tonnes of carbon per ha per year in temperate grassland, even after accounting for the effect of increased temperatures on decomposition (Van Ginkel, *et al.*, 1999). In areas benefiting from precipitation increases, greater photosynthesis and growth may counteract the warming effect, but this depends also on changes in the seasonality of precipitation and the net effect of warming on evapotranspiration. Temperature and CO_2 changes also will affect species composition, through change in the optimal growth ranges for different species, plant composition and species competition. For example, legume species in grasslands and the proportion of browse in rangelands are likely to increase with rising CO_2 (Thornton, *et al.*, 2008), in turn affecting carbon sequestration rates in soils and plants.

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[1] C3 plants, which account for more than 95 percent of earth's plant species, use an enzymatic reaction (via rubisco) to make a three-carbon compound as the first stable product of carbon fixation. C3 plants flourish in cool, wet and cloudy climates where light levels may be low, because the metabolic pathway is more energy efficient and, if water is plentiful, the stomata stay open and let in more carbon dioxide. Carbon losses through photorespiration are high.

[2] C4 plants possess biochemical and anatomical mechanisms to raise the intercellular carbon dioxide concentration at the site of fixation, which reduces, and sometimes eliminates, carbon losses by photorespiration. C4 plants, such as sugar cane, inhabit hot, dry environments and have very high water-use efficiency, allowing up to twice as much photosynthesis per gram of water as in C3 plants, but C4 metabolism is inefficient in shady or cool environments. Less than 1 percent of the earth's plant species can be classified as C4.

The impacts of climate change are likely to be highly spatially variable, but developing countries, many in Africa, generally are considered more vulnerable than developed countries due to their lower capacity to adapt (Thomas and Twyman, 2005). Poor people are particularly vulnerable and population growth is an added challenge that exacerbates pressures on natural resources and poverty. Africa's population has been projected to more than double – from 0.9 to 2 billion – from 2005 to 2050 (UNDP, 2007). Climate change and variability will have serious implications, impacting on ecosystems goods and services upon which poor people and livestock keepers depend, thus exacerbating current development challenges.

Soil carbon sequestration may serve as a bridge in addressing the global issues of climate change, desertification and loss of biodiversity, and is thus a natural link among the three related UN conventions (Lal, 2004). Co-benefits of carbon sequestration also may provide a direct link to the Millennium Development Goals (MDGs) through their effects on food security and poverty. To tackle development challenges effectively in the context of climate change, it will be necessary to demonstrate the linkages among land-use change (deforestation and conversion among forest, grasslands and croplands), land resources management (soil, water, vegetation and biodiversity management) and the vulnerability or resilience of local livelihoods.

LAND DEGRADATION AND DROUGHT

The recent Global Assessment of Land Degradation and Improvement (GLADA) study (Bai, *et al.*, 2008) estimated that some 22 percent of drylands were degraded, with some 8 percent of degradation found in the dry subhumid regions, 9 percent in the semi-arid regions, and 5 percent in arid and hyper-arid regions.[3] The various land degradation processes are being driven mainly by poor land management. Despite the always gloomy predictions of land degradation, GLADA found that drylands do not figure strongly in ongoing land degradation.[4] The recovery of the Sahel from the droughts of the 1980s is a notable example (Bai, *et al.*, 2008).

The various land degradation processes are being driven mainly by poor land management. Up to 71 percent of the world's grasslands were reported to be degraded to some extent in 1991 (Dregne, *et al.*, 1991) as a result of overgrazing, salinization, alkalinization, acidification and other processes (FAO/LEAD, 2006). Grasslands and rangelands in arid, semi-arid and subhumid areas are particularly affected (Safriel, *et al.,* 2005).

Carbon losses due to soil erosion can influence soil C storage on rangelands, both by reducing soil productivity from the eroding sites and potentially increasing it in depositional areas (Schuman, *et al.,* 2002). Thus, there is a redistribution of the soil carbon as a result of soil erosion.

In addition to redistribution, land management practices also can cause differences in mineralization rates of soil organic matter. Changes in rangeland soil C can occur in response to a wide range of management and environmental factors. For example, grazing, fire and fertilization practices as well as conversion of grasslands into croplands affect soil carbon storage in rangelands (Conant, *et al.*, 2001; Schuman, *et al.*, 2002).

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[3] The study used remote sensing analysis based on the normalized difference vegetation index (NDVI) adjusted for rainfall and energy use efficiency.

[4] Australia is an exception.

PHOTO 3
Erosion of alpine grassland surface vegetation and topsoil emits CO_2 (Zeku country, Qinghai province, China)

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Cropping systems in general have lower carbon retention in rangeland areas. Chan and Bowman (1995) noted that cropping soils over a 50-year period in semi-arid New South Wales, Australia, resulted in an average percentage reduction in soil carbon of 32 percent as compared to pasture systems. Rates of reduction were directly related to the number of years of cropping (FAO, 2004). A meta-analysis of 80 reports on conversion of grassland to cropland (Guo and Gifford, 2002) found that this conversion always led to a loss of soil carbon. The average loss was 59 percent, with the highest loss (some 78 percent) in areas with low annual rainfall of 400–500 mm. This relationship will become more important if land used for biofuels continues to compete with more permanent forms of land use and soil cover.

Worldwide, some 18–28 billion tonnes of carbon are estimated to have been lost as a result of desertification (i.e. (persistent) land degradation in drylands)[5], and grazing-induced desertification in the drylands has been estimated to emit as much as 100 million tonnes of CO_2 per year (FAO/LEAD 2006). Potentially, much of the loss can be re-sequestered through soil and vegetation restoration (IPCC, 1996). Degradation of dryland soils means that they are far from saturated (in carbon) and thus potentially have a significant capacity to store more carbon (Farage, *et al.*, 2003). The technical potential of carbon

[5] Desertification is defined as "persistent land degradation in arid, semi-arid and dry sub-humid areas", with land degradation being defined as the "reduction or loss of biological or economic productivity" (UN Convention to combat desertification, 2004) or the "reduction in the capacity of the land to perform ecosystem functions and services that support society and development (LADA, 2009).

sequestration through desertification control and restoration has been estimated at 12–18 billion tonnes of carbon over a 50-year period (Lal, 2001, 2004b).

Increasing the amount of carbon sequestered as soil organic matter can enhance rainfall effectiveness through increased water holding capacity and water source replenishment to better withstand times of drought. Carreker, *et al.* (1977) demonstrated the direct relationship between soil organic carbon infiltration and time taken for water to run-off the land. Thurow, *et al.* (1988) showed that infiltration was directly related to percentage of ground cover.

It is estimated that the area affected by drought will double by the end of the century (from 25 to 50 percent) and drought periods will likely last longer. Impacts are already being reported. The mean annual number of people estimated to have died or been severely affected by drought in East Africa increased tenfold in the 30 years from 1974 to 2003 – from 584 per 100 000 to 6 067 per 100 000 (Guha-Sapir, *et al*., 2004).

The increased extent and duration of drought periods will impact the sustainability, viability and resilience of livestock and cropping systems and livelihoods in drylands. Moreover, post-drought recovery of pastoral systems through, for example, herd reconstitution and replenishment of water sources, will be less dependable (Hadley Centre, 2006). Sub-Saharan Africa is uniquely vulnerable as it already suffers from high temperatures, less predictable rainfall and substantial environmental stress (IMF, 2006). In this region, the poor are expected to suffer the greatest repercussions from scarce water resources.

Pressures on resources from expanding human and livestock populations and inappropriate land resources management practices are exacerbating land degradation which, in turn, affects capacities to cope with drought. Reduction or loss of surface vegetative cover is a critical factor as it results in accelerated runoff and erosion which increases the severity and extent of degradation and further reduces resilience to drought. Estimates of more than 70 percent water loss to evaporation have been noted on bare ground (Donovan, 2007) – an unaffordable loss at a time of increasing drought risk. Resource degradation and impacts on ecosystem services and vulnerability can only be addressed through a major change in the behavior of the populations concerned – both sedentary and nomadic peoples.

BIODIVERSITY

Some studies suggest that the potential biodiversity of rangelands is only slightly less than that of forests, and that the low levels of diversity currently recorded in many of the world's rangelands is a result of human influence (Blench and Sommer, 1999). This conclusion is limited, however, by inadequate research in and knowledge of many rangeland ecosystems. Nevertheless, there is evidence that the biodiversity of the world's rangelands is declining alarmingly, through mismanagement, inappropriate habitat conversion and, more recently, due to climate change. The Millennium Assessment estimated that climate change will be the main driver of biodiversity loss by the end of the century (IIED/WWF, 2007).

Climate change has been observed to affect grassland biodiversity. Studies in the Qinghai-Tibet Plateau – an area very sensitive to climate change – have shown that a trend of warming and drying is driving a transition of highly productive alpine-adapted *Kobresia* communities to less productive steppe *Stipa* communities. Changes in growing season precipitation, in particular, have been found to be associated with declines in grassland species richness (Wilkes 2008).

Biodiversity loss in rangelands is directly affected by overgrazing – typically livestock returning to re-graze plants before adequate recovery – and by land degradation which causes changes in species composition and intra-species competition. This is exemplified by bush encroachment and loss of less-resilient plant species and loss of habitat and associated species that provide support functions, such as predation and pollination. The International Union for Conservation of Nature (IUCN) has identified livestock management as one of the threats to as many as 1 700 endangered species (FAO/LEAD, 2006).

Land conversion is the other main cause of biodiversity loss. For example, of the 13 million ha of forest lost annually (FAO, 2005), land cleared for livestock accounts for some 1.5 million ha per year (De Haan, *et al.*, 2001), resulting in severe loss of habitat and species. Increasingly, constraints of poor soils and seasonal climate in rangeland are overcome through investments in commercial livestock production (ranching) or use of high inputs of fertilizers and seeds for rainfed crops, such as growing of soybeans in the Brazilian *cerrado,* or irrigated agriculture where adequate water is available.

There is a significant relationship between patterns of species richness, habitat area and degree of stability. Where greater levels of biodiversity have been conserved, post-drought recovery of the ecosystem is much more rapid than in less diverse areas (Tilman and Downing, 1994). Africa's pastoralists have developed very resilient grazing systems that manage to maintain relatively high human populations on rangelands of low and highly variable productivity. They use a mixture of species (cattle, sheep, goats, camels) and traditional breeds mainly selected for adaptation to the harsh environment. Small ruminants with their higher reproductive rate play a key role in building up livestock populations after periodic droughts have led to destocked systems (FAO/LEAD, 1995).

Extirpation of native grazers, habitat fragmentation, increased nitrogen deposition from the atmosphere and altered fire frequency are major causes of disruption in grassland ecosystems worldwide (WRI, 2000). In savannas, fire is often used to improve the quality of the grass cover through stimulating new shoots, a short-term gain that reduces woody cover and leads to land degradation if livestock numbers are too high, which is commonly the case (Solbrig, 1996).

Biodiversity loss in rangelands has significant implications in terms of vulnerability to climate change and the food security of those directly dependent on rangelands as well as those living outside rangelands but who depend on livestock for protein (Blench and Sommer, 1999). Studies on degraded agro-ecosystems in Sudan have shown that maintaining and promoting the use of biodiversity in grasslands can increase soil C sequestration, while sustaining pastoral and agricultural production (Olsson and Ardo, 2002). Innovative approaches to achieving both livelihood and biodiversity goals include: grazing for habitat management, cooperative corridors, adaptations of traditional pastoralism, co-management of livestock and wildlife, disease and predator management, and game ranching (Neely and Hatfield, 2007).

LIVESTOCK

Livestock production is considered responsible for 37 percent of global anthropogenic methane (CH_4) emissions and 65 percent of anthropogenic nitrous oxide (N_2O) emissions (FAO 2006b, FAO/LEAD, 2006). Methane from enteric fermentation globally is reported to be 85.63 million tonnes while manure contributes 18 million tonnes of CH_4 per year (FAO/LEAD, 2006). Of the total methane emissions from

BOX 1

North America case study: Konza Prairie

A grassland research study conducted by the National Science Foundation (NSF) at the Konza Prairie long-term ecological research site in northeastern Kansas, USA, demonstrated that diversity and productivity of tall grass prairies are controlled to a large extent by nitrogen availability. Historically, this has been driven by interactions between frequency of fires and grazing by large herbivores. In general, spring fires enhance growth of certain grasses, and herbivores preferentially graze these grasses – keeping a system of checks and balances working properly and allowing many plant species to flourish.

The NSF scientists showed that although burning is essential to maintaining tall grass prairies, it is not a sufficient management solution for restoring prairie diversity. Grazing of herbivorous mammals, such as bison or cattle, can be used as a management tool to maintain or even enhance plant species diversity. This management tool is effective even during periods of frequent burning and other stresses, i.e. conditions that would otherwise lead to biodiversity decline. Indeed, bison have historically served as keystone species in such grassland ecosystems (NSF, 1998).

Source: Morocco IMT country profile (2003).

enteric fermentation, grazing systems contribute some 35 percent compared to 64 percent for mixed farming systems (FAO/LEAD, 2006).

IPCC (2007) has reported that pasture quality improvement can be important in reducing methane, particularly in less developed regions because this results in improved animal productivity and reduces the proportion of energy lost as CH_4. The technical mitigation potential of grazing systems' carbon sequestration (discussed later in this paper) is considered significantly higher than methane emissions resulting from enteric fermentation or manure management. Land degradation from overgrazing of plants decreases re-absorption of atmospheric CO_2 by vegetation re-growth (FAO/LEAD, 2006). Therefore, non-CO_2 emissions should be addressed in the context of whole systems analysis and net GHG mitigations (FAO, 2009).

Improvements in livestock management are required to prevent overgrazing and resulting soil and vegetation degradation in order to enhance carbon sequestration, increase the efficiency of feeding systems and reduce net GHG emissions. Besides improving the sustainability of resource management and livelihoods in drylands, increasing productivity of extensive grazing systems also will contribute to meeting the growing demand for livestock products that is currently mostly being met by increasing intensification of livestock production. Intensive production is increasing dramatically as a result of changing consumption patterns in favour of meat and dairy products, especially among increasingly urban and better-off populations. Between 1999 and 2030, global per capita increases in consumption of livestock products are anticipated to be 20 percent for meat and 13 percent for milk. In sub-Saharan Africa, the increases are anticipated to be 30 percent for meat and 14 percent for milk over the same time period (WHO/FAO 2002).

FIRE

Annual burning of tropical grasslands plays a significant role in the global carbon cycle. The amount of carbon associated with biomass burning is staggering. In 2000, burning affected some 4 million km^2 globally, of which more than two thirds was in the tropics and subtropics (Tansey, *et al.*, 2004) and 75 percent outside of forests. Large areas of savannah in the humid and subhumid tropics are burned every year for rangeland management, totaling some 700 million ha worldwide. This is especially severe in

Africa where about 75 percent of grasslands are burned annually. In the year 2000, savannah burning represented some 85 percent of the area burned in Latin American fires, 60 percent in Africa and 80 percent in Australia (FAO/LEAD, 2006).

The amount of carbon released just by burning grasslands worldwide is estimated at 1.6 Gt C per year (Andreae, 1991; Andreae and Warneck, 1995). A research project on productivity and photosynthesis in tropical grasslands, conducted by the United Nations Environment Programme in three grassland sites, determined that the gross flux of carbon from burning of tropical grasslands falls in the range 2.4- 4.2 Gt C per annum (UNEP, 2006). The significance of these figures is notable when compared to the net fluxes of 1.8 Gt C estimated from deforestation and of 5.5 Gt C per year from fossil fuel combustion (Savory and Peck, 2007; Hall and Scurlock, 1991).

Biomass burning in the savannahs destroys vast quantities of dry matter per year and contributes 42 percent of gross carbon dioxide to global emissions (Levine, *et al,* 1999; Andreae, 1991). This is three times more than the CO_2 released from burning rainforests. However, savannah burning is not considered to result in net CO_2 emissions since equivalent amounts of CO_2 released in burning can be recaptured through photosynthesis and vegetation re-growth. In savannah systems that contain woody species, it has been shown that the carbon lost by fire can be replaced during the following season (Ansley, *et al.,* 2002). However, in practice, grasslands that are burned too often may not recuperate (DeGroot, 1990), resulting in permanent loss of protective vegetation cover and productivity.

Moreover, burning releases other globally relevant gases (NO_2, CO and CH_4) as well as photochemical smog and hydrocarbons (Crutzen and Andreae, 1990; FAO/LEAD, 2006). Aerosols produced by the burning of pasture biomass dominate the atmospheric concentrations of aerosols over the Amazon basin and Africa (FAO/LEAD, 2006).
In addition to the losses from vegetation, biomass burning significantly reduces soil organic carbon (SOC) in the upper few centimeters of soil (Vagen, *et al.*, 2005). The intensity and speed of the fire will govern the depth to which the soil is affected. In one study where burning was used to clear forests, 4 tonnes C/ha was lost in the top 3 cm of soil, but this was replaced within one year under a pasture system (FAO, 2004).

Burning of bushes and grasslands, and subsequent loss of soil organic matter have other negative effects on ecosystem function and resilience. It leads to reduced soil water retention capacity, kills micro-organisms in the surface soil and reduces their food substrate, exposes the soil to erosion and, in some soils, increases soil surface hardness (NARO, IDRC, CAB International, n.d.) which further reduces rainwater infiltration and soil biological activity. Thus, while fire may seem attractive for biomass removal and growth stimulation, it results in atmospheric pollution, the loss of many nutrients which would be recycled in the grazing process, loss of surface litter, and bare ground with a frequently capped soil surface which inhibits water infiltration (Savory, 1988). Seasonal timing of burning can make some difference to the impact of the burn on soil and vegetation (Daowei and Riply, 1997).

Where possible, alternatives to grassland burning should be found. Measures to control burning to reduce both the intensity and frequency of fires should be put in place to limit negative consequences of carbon and other gaseous emissions, and to reduce degradation of soil and vegetation and associated loss of productivity and ecosystem functions.

Estimates of Potential Carbon Storage and Sequestration

IPCC (2007) reports that soil carbon sequestration is the mechanism that holds the greatest technical mitigation potential within the agricultural sector. Lal (2003) estimates that the potential of soil C sequestration to offset emissions is 0.4 to 1.2 Gt. C per year, or 5 to 15 percent of global emissions. Smith, *et al.* (2008) estimate that improved grassland management and restoring degraded soils together have the potential to sequester around 2000 Mt CO2e per year by 2030.

CARBON STOCKS

Grasslands overall occupy some 3.4 billion ha, or about 26 percent of emerged lands. They have a large potential to affect the amount of carbon in the atmosphere (IPCC, 2001). Globally grasslands store up 8 percent of the world's carbon (IPCC, 2001).

Grasslands store considerably more carbon in soils than in the vegetation (White, *et al.*, 2000). While carbon storage in grasslands is less per unit area than forests, the total amount of carbon that grasslands store is significant because the area of these ecosystems is so extensive (White, *et al.*, 2000). Estimates of carbon storage for each dryland region indicate that 36 percent of total carbon storage worldwide is in the drylands, and 59 percent of the total carbon stock held in Africa is in the drylands (Campbell, *et al.*, 2008; UNEP, 2008). Table 1 shows the estimated total carbon stocks in vegetation and soils of tropical savanna, temperate grasslands and desert–semi-desert biomes.

The productivity of tropical grasslands is now known to be much higher than was previously thought (FAO, 2004, UNEP, 2006). When accounting for future climate change, the carbon stock in grasslands continues to be significant. Petri, *et al.* (2009), using a geographic information system (GIS) simulation tool, predicted that the influence of climate change on carbon sequestration and management practice in grasslands out to 2080 could result in a 6 percent increase in carbon stocks as compared to the present climate scenario.

POTENTIAL FOR CARBON SEQUESTRATION

There is a great potential for carbon sequestration in drylands because of their large extent and because substantial historic carbon losses mean that drylands soils are now far from saturation (FAO/LEAD, 2006). Lal (2004) estimates that soil carbon sequestration in the dryland ecosystems could achieve about 1 billion tonnes C per year but reaching this will require a vigorous and coordinated effort at a global scale. Smith, *et al.* (2007) estimate that improved rangeland management has the biophysical potential

Table 1. Stocks in vegetation and 1 metre depth of soil (Watson, *et al.*, 2000)

Biome	Area in Km^2	GT C in Vegetation	GT C in Soils	Total GT C
Tropical savanna	22.5	66	264	330
Temperate Grasslands	12.5	9	295	304
Desert–semi-desert	45.5	8	191	199

to sequester 1.3 – 2Gt CO_2e worldwide to 2030. Potential sequestration for Australian rangelands is estimated at 70 million tonnes C per year (FAO LEAD, 2006).

The scope for soil organic carbon gains from improved management and restoration within degraded and non-degraded croplands and grasslands in Africa is estimated at 20–43 Tg C per year, assuming that best management practices for improving soil health can be introduced on 20 percent of croplands and 10 percent of grasslands. Research shows that soils can continue carbon sequestration for up to 50 years (Lal, *et al.*, 1998; Conant, *et al.*, 2001). Even under an assumption that near steady state levels may be reached after 25 years of sustained management, this would correspond with a mitigation potential of 4–9 percent of annual CO_2 emissions in Africa (Batjes, 2004).

The carbon sink capacity of the world's agricultural and degraded soils is said to be 50–66 percent of the historic carbon loss from soils, or some 42–78 Gt of carbon (Lal, 2004). Restoring land health on large areas of degraded land could thus compensate for significant amounts of global carbon emissions. Dryland pasture soils are prone to degradation and desertification and have led to dramatic reductions in the SOC pool. Although many of the grassland areas in drylands are poorly managed and degraded, it also follows that they offer potential for carbon sequestration (FAO, 2004) to replace lost SOC. Returning degraded soils to grassland can restore depleted SOC while also reducing erosion-induced emissions of CO_2 (FAO/LEAD, 2006).

There exists a high potential for increasing SOC through establishment of natural or improved fallow systems (agroforestry and managed resting of land for recovery from overgrazing) with attainable rates of C sequestration in the range of 0.1–5.3 Mg C/ha/yr. Fallow systems generally have the highest potential for SOC sequestration in sub-Saharan Africa, with rates up to 28.5 Tg C per year (Vagen, *et al.*, 2005).

Furthermore, there is some evidence that dry soils are less likely to lose carbon than wet soils. Residence time of carbon in dryland soils is sometimes even longer than in forest soils (Dregne, 2002). While the percentage of carbon that can be sequestered is low, it may be an effective way to sequester carbon long-term (FAO, 2004). This may prove to be a cost-effective method for carbon sequestration, particularly taking into account the side benefits of soil improvement and restoration and related social and economic benefits.

However, to date, there has been little documentation of implementation and opportunity costs of uptake of carbon sequestrating management practices. Taking just the grasslands in Africa, Batjes (2004) estimated that using technologically available methods to improve management on only 10 percent of the area would achieve gains in soil carbon stocks of 1 328 million tonnes C per year for some 25 years.

IMPROVING MANAGEMENT PRACTICES

Since grazing is the largest anthropogenic land use, improved rangeland management could potentially sequester more carbon than any other practice (IPCC, 2000 in FAO/LEAD, 2006). Given the size of the C pool in grazing lands, it is important to improve understanding of the current and potential effects of grazing land management on soil carbon sequestration and storage (Schuman, *et al.,* 2002).

Conant, *et al.* (2001) reviewed 115 published studies on the impacts of specific management practices on soil carbon sequestration in rangelands globally. Management improvements included fertilization to increase forage production, improved grazing management, conversion from cultivation and native vegetation, and a few studies of sowing of legumes and grasses, earthworm introduction and irrigation. Analysis showed that climatic variables, native vegetation, depth, time and original soil C all affect rates of soil C change but, on average, management improvements and conversion into pasture lead to increased soil C content and to net soil C storage. Carbon sequestration rates were highest during the first 40 years after treatments began and tended to be greatest in the top 10 cm of soil. Impacts were greater in woodland and grassland biomes than in forest, desert, rain forest or shrub land biomes. The largest increases resulted from cultivation, the introduction of earthworms and irrigation.

Proper grazing management has been estimated to increase soil C storage on USA rangelands from 0.1 to 0.3 Mg C ha per year and new grasslands have been shown to sequester as much as 0.6 Mg C per ha per year (Schuman, *et al.*, 2002). Drawing on a global database, Conant, *et al.* (2001) found that improved grazing can sequester from 0.11 to 3.04 Mg C per ha per year, with an average of 0.54 Mg C per ha per year. Since carbon sequestration in response to changes in grazing management is influenced by climatic variables, the sequestration potential in different regions varies.

Conant and Paustian (2002) estimated that a transition from heavy to moderate grazing can sequester 0.21, 0.09, 0.05, 0.16, and 0.69 Mg C ha per year in Africa, Australia/Pacific, Eurasia, North America and South America, respectively. They also estimated, at a very general level, a potential sequestration capacity of 45.7 Tg C per year through cessation of overgrazing, although research also has found that some grasslands sequester more carbon in response to heavier grazing intensities. Reeder and Schuman (2002) reported higher soil C levels in grazed – compared to un-grazed – pastures, and noted that when animals were excluded, carbon tended to be immobilized in above-ground litter and annuals that lacked deep roots. After reviewing 34 studies of grazed and ungrazed sites (livestock exclusion) around the world, Milchunas and Lauenroth (1993) reported soil carbon was both increased (60 percent of cases) and decreased (40 percent of cases).

PHOTO 4

Grassland degradation in Zeku county, Qinghai province, China.

ANDREAS WILKES, ICRAF

IPCC (2007) reported several measures for improve grasslands in light of mitigation and carbon sequestration including: managing grazing intensity and timing, increasing productivity, management of nutrients, fire management and species introduction. In addition to these common livestock management practices, Tennigkeit and Wilkes (2008) identified the adoption of alternative energy technologies that replace use of shrubs and dung as fuel as a management practice highly relevant to dryland ecosystems.

In addition to carbon sequestration, management practices that reduce emissions of other GHGs should also be considered. The fact that ruminants are a significant source of CH_4 through enteric fermentation must be taken into consideration when exploring carbon budgets. There are indications that rotational grazing grassland management strategies that improve plant productivity and animal nutrition may reduce CH_4 emissions per land unit (Deramus, *et al.,* 2003).

Additional carbon and nitrogen emissions associated with the adoption of improved management practices must be considered when estimating the C sequestration potential of grassland soils with improved management. One study modeled the influence of pasture fertilization on soil C and found that pasture soils sequestered 0.16 Mg C per ha per year with application of 70 kg N per ha per year but – since 1.4 kg C are emitted per kg of nitrogen manufactured – net C sequestration would be reduced to 0.06 Mg C per ha per year (Lee and Dodson, 1996). Nitrogen fertilizer applied to grasslands also contributes significantly to N_2O emissions (Oenema, *et al*., 1997). In addition to direct N_2O emissions from N fertilizer application, current UNFCCC guidance on the use of fertilizers in GHG emission reduction projects directs that the emissions from processes embodied in production of the fertilizer used should also be deducted from sequestration estimates (UNFCCC, 2007a).

Improving Carbon Cycling and Grassland Management

Soil carbon stems from soil organic matter and, as Lal (2004) has noted, irrespective of its climate change mitigation potential, soil C sequestration has merits for its impacts on increasing productivity, improving water quality and restoring degraded soils and ecosystems. Organic matter has various interrelated effects on soil fertility. These can be distinguished as physical (e.g. improved structural stability, erosion resistance, water-holding capacity and aeration), chemical (e.g. enhanced availability of micronutrients) and biological (e.g. enhanced faunal activity) effects (FAO, 1995). High SOC stocks are needed to maintain consistent yields through improvements in water- and nutrient-holding capacity, soil structure and biotic activity (Lal, 2004).

Sequestering soil carbon in well-managed grasslands and rangelands provides both mitigation and adaptation benefits. It reduces water losses from evaporation and run-off, thus taking advantage of the rain that does fall, and also can enhance biological diversity.

Jones (2006) identified several factors that reduce SOM and disrupt the water cycle, including the loss of perennial groundcover, intensive cultivation, bare fallows, stubble and pasture burning, and continuous grazing. Improved grazing is considered a strategy for restoring soil and increasing land resilience while building the carbon pool.

ELEMENTS OF GOOD GRASSLAND AND GRAZING MANAGEMENT

In defining good grazing management, Jones (2006) identified several elements, including: understanding how to use grazing to stimulate grasses to grow vigorously and develop healthy root systems; using the grazing process to feed livestock and soil biota; maintaining 100 percent plant and litter cover 100 percent of the time; rekindling natural soil forming processes; and providing adequate rest from grazing without over-resting. This final element recognizes that livestock's grazing of the most palatable grasses provides a competitive advantage to the less palatable grasses for water and nutrients.

Savory and Butterfield (1999) identified three key insights related to using grazing and animal impact as tools for healing degraded land.

a) Grazing lands evolved from an historical predator-prey relationship, with pack-hunting predators keeping large herds of ungulates bunched and moving (McNaughton, 1997). Healthy grasslands are still achieved in drylands by bunching the stock into large herds and moving them frequently. Controlled grazing allows for more even distribution of dung and urine that can enhance soil organic matter and nutrients for plant productivity thus regenerating grasslands and improving livestock production simultaneously.

b) Overgrazing is a function of time (grazing and recovery) and not of absolute numbers of animals – it results when livestock have access to plants before they have time to recover. Compromised root systems of overgrazed plants are not able to function effectively. Unmanaged grazing or complete exclusion from grazing often will lead to desertification and loss of biodiversity in all but high rainfall areas (Jones, 2006). In medium-to-low rainfall areas, grasses which are not grazed can become senescent and cease to grow productively (McNaughton, 1979). Niamir-Fuller (1999) also notes that grassland productivity is dependent on the mobility of livestock and herders, the length of continuous grazing on the same parcel, the frequency with which the patch is re-grazed, dispersion of animals and herds around the camp, and the interval during which the patch is rested. These insights are consistent with the observed practices of traditional pastoralist communities across the world (Nori 2007).

c) Land and plants respond differently to management tools, depending upon where they are found on the 'brittleness' scale. Brittleness is based on the distribution of moisture throughout the year.

Based on these principles, a planned grazing method has been developed to: improve soil cover, increase water infiltration/retention, improve plant diversity/biomass, control the time the plant is exposed to grazing, increase animal density and trampling, distribute dung and urine, and improve livestock quality and productivity while maintaining grasslands with livestock. For example, Thurow, *et al.* (1988) showed that water infiltration increased under moderate, continuous grazing, while it decreased to some extent under short-duration grazing and even more under heavy continuous grazing over a 6-year period.

Non-equilibrium systems, in which rainfall timing and distribution are highly variable, are found in arid and semi-arid environments. In these areas, it has been noted that extreme variability in rainfall may have greater influence on vegetation than the number of grazing animals (Behnke, 1994). Grazing management in these ecosystems requires

PHOTO 5
The Loita community has successfully held back the break up of their common land-holdings, allowing therm to move livestock in response to ecological cycles. It remains one of the most sustainable rangeland management practices in Southern Kenya today

PHOTO: DAVID BOERMA

PHOTO 6
Maasai elders in Mosiro, Kenya, discussing the impacts of the ongoing drought

adaptive planning – the use of guidelines and principles in a continuous iterative process instead of prescripts such as uniform stocking rates. This does not imply that the concept of carrying capacity has been rejected. However, continuous monitoring of livestock productivity and range condition and productivity, and learning lessons from experience and practice can provide the framework that will allow an appropriate response to adapt to changing circumstances (climatic and socioeconomic).

Research by Rowntree, *et al.* (2004) supports ecologists' contention that communal grazing systems do not necessarily degrade range condition relative to management systems based on a notional carrying capacity. In this regard, Niamir-Fuller (1999) points out that pastoralists can maintain higher populations of herbivores sustainably if they have ensured and flexible access to the different habitats and resources in a given area.

Grazing can be considered a management tool to enhance the vigor of mature perennial grasses by increasing their longevity and promoting fragmentation of decaying, over-mature plants by encouraging basal bud activation, new vegetative and reproductive tiller formation as well as seed and seedling production. The positive effect of grazing results from the effect that it has on species composition and litter accumulation (FAO, 2004).

The key factor responsible for enhanced carbon storage in grassland sites is the high carbon input derived from plant roots (FAO, 2004). Deep, fibrous root systems provide multiple benefits, including soil aeration, erosion control, enhanced nutrient cycling, soil building, increased water-holding capacity and reduced groundwater recharge. They also provide habitat and substrate for soil biota such as free-living nitrogen fixing bacteria.

Improved grasses and legumes mixtures have a relatively large percentage of C sequestered in the fine root biomass, which is an important source of C cycling in the soil system (Mannetje, 2008). Thus, one of the most effective strategies for sequestering carbon is fostering deep-rooted plant species on land used for agriculture, through rotations that include grass fallow or grass leys, and integrating fodder crops, cover crops or perennial species into the cropping systems.

Introduction of nitrogen-fixing legumes and high productivity grasses or addition of fertilizer can increase biomass production and soil carbon pools but may decrease biodiversity. Introduction of exotic nitrogen fixers poses the risk that the introduced species become invasive. Irrespective of whether grazing land is intensively managed or strictly protected, carbon accumulation can be enhanced through improvement practices, especially if native species are properly managed to enhance the biodiversity associated with the system (Secretariat of the Convention on Biological Diversity, 2003)

Socio-Economic Dimensions of Grassland Management and Climate Change Mitigation

THE POLITICS OF PROMOTING IMPROVED MANAGEMENT IN PASTORAL AREAS

Raising livestock on drylands through seasonal migration is a uniquely efficient way to make use of lands that are unsuitable for other forms of agriculture. Rangeland resources are typically heterogeneous and dispersed, with their variation tied to seasonal patterns and variable climatic conditions. Livestock keepers who inhabit these regions must contend with variable climatic conditions that regulate range productivity, among which rainfall patterns play a major role. Other relevant biophysical variables include soil quality, vegetation composition, fire events and disease outbreaks (Behnke, *et al.*, 1993).

Many researchers studying pastoral systems have concluded that extensive livestock production on communal land is the most appropriate use of semi-arid lands in Africa (Behnke, *et al.*, 1993; Scoones, 1994). Nori (2007) argues that the mobility and flexibility of pastoral systems enables them to make the best use of the patchy and fragile environment. When compared to ranching models, pastoral systems are found to be more productive per unit area due to the ability of pastoralists to move their herds opportunistically and take advantage of seasonally available pastures (Sandford, 1983) and to be more economically feasible than either sedentary or ranching systems (Niamir-Fuller, 1999).

However, pastoral communities remain among the most politically and economically marginalized groups in many societies (Nori, *et al.*, 2005). Galaty (1992) notes that migratory herding cultures find themselves facing insecurity in multiple dimensions, including land, political, food, environmental and physical insecurity. Many exist in persistent states of crisis due to drought, disease, raids, pastures and the fact that their transit routes are shrinking in the face of spreading cultivation, nature conservation and control of movements across international borders. Pastoral marginalization comes from global processes involving structural adjustment, policy modernization and economic liberalization (Nori, *et al.*, 2005).

De facto common property resources that are commonplace in rangelands, and unclear private user rights for individual farms or plots of land encourage short-term resource exploitation rather than long-term conservation. Moreover, changes in land tenure may alter the behaviour of individuals and local communities, leading to land degradation – for example, overgrazing following the settlement of nomads (FAO, 2000). Key constraints stemming from lack of tenure, promotion of privatization, and minimal health and education services and security must be addressed to ensure that the synergistic relationship between livestock-based livelihoods and environmental health can be successful and sustainable.

There are several cooperative efforts to enhance the voice of pastoralist groups. For example, the Segovia Declaration was put forward at the Convention to Combat Desertification (CCD) in 2007 by the participants of the World Gathering of Nomadic and Transhumant Pastoralists. The pastoralists, identifying the loss of grazing lands to crops and agrofuels as a critical concern, called for support such as: recognition of common property rights and customary use of natural resources; respect for customary laws, institutions and ownership; full participation in policy-making decisions affecting their access to natural resources and economic and social development; and development of strategies and mechanisms to support pastoralists in reducing the impact of drought and climate change. Because biofuel production increasingly targets marginal farm lands, pastoralists have been identified as particularly vulnerable to losing access to essential grazing lands (Cotula, *et al.*, 2008).

Improving pastoralists' capacities to cope with degradation and drought, and promoting sustainable and integrated management of croplands, rangelands and water resources requires a combination of measures. These can include adaptive management approaches, social organization and development of locally adapted regulations for resource access, and tenurial arrangements that cover the common property resources upon which millions of poor people depend for their livelihoods.

SOCIO-ECONOMIC ISSUES IN PASTORALISTS' ACCESS TO CARBON MARKETS

Within the context of international carbon markets, there must be clear tenure rights over land enrolled in carbon sequestration programmes. In many areas of the world, rangeland tenure has already been privatized and, in some areas, communal tenure of rangeland is officially recognized. However, where land tenure is unclear or land owners are unable to exclude others from use of rangelands, it will be difficult to ensure that recommended carbon sequestrating activities are implemented. In describing a situation of multiple stakeholders with customary use rights over the same grazing lands, Roncoli, *et al.* (2007) argued that carbon sequestration projects in such contexts will need to facilitate multi-stakeholder negotiation and conflict management while protecting the interests of minorities and marginalized groups. Tennigkeit and Wilkes (2008) evaluated the potential for carbon finance in rangelands and also stressed that tenure issues are likely to be the main constraint on pastoralists accessing carbon markets.

In reviewing West African rangelands' potential for sequestering carbon, Lipper, *et al.* (2008) noted that West Africa already has a network of community-based natural resource management projects that can provide an institutional basis for linking pastoralists with carbon markets. However, they cautioned that the transaction costs of making this linkage may be high. Given low per ha sequestration rates in the region and low current prices of carbon, carbon markets may not be able to support implementation of carbon sequestrating management practices in the absence of external co-financing.

Cacho (2009) and Cacho and Lipper (2006) analyzed the implications of abatement costs (costs of implementing mitigation practices) and transaction costs in development and implementation of agricultural smallholder carbon finance projects. Since a certain proportion of transaction costs is relatively fixed per project, there is a minimum scale of project at which the transaction becomes feasible for a given price of carbon. These constraints may be overcome if existing management structures or collective action among smallholders can be used to increase the project size without significantly increasing transaction costs. Thus, strengthening rural institutions and securing resource tenure are key elements of a sustainable and equitable carbon sequestration strategy.

The economic feasibility of carbon sequestration in grasslands also depends on the price of carbon. IPCC (2007) notes that at USD 20 per tCO_2e, grazing land management and restoration of degraded lands have potential to sequester around 300 Mt CO_2e up to 2030; at USD 100 per tCO_2e they have the potential to sequester around 1400 Mt CO_2e

over the same period. These potentials put grassland carbon sequestration into the category of 'low cost' and readily available mitigation practices. A study of mitigation options in China (Joerss, *et al.*, 2009) also suggested that grassland mitigation options were among the lowest cost and most readily available options. However, existing projections appear to have assumed very low implementation costs. There is scant documentation of implementation costs for grassland management and degraded land restoration activities (UNFCCC 2007b).

Tennigkeit and Wilkes (2008), analyzing existing studies of the economics of carbon sequestration in pastoral areas, suggested that in addition to the possible high costs of adopting many types of improved management practice, the economics of adoption are affected by the differences in resource endowments of poorer and wealthier households, and by the seasonality of income and expenditure flows. Before a realistic analysis of economic potential can be made, much more documentation is required, especially in developing countries, of the economics of sequestration in grassland areas. This includes both implementation costs and the opportunity costs to households of adopting new management practices.

Despite this limited current knowledge, carbon sequestration programmes have the potential to provide economic benefits to households in degraded dryland ecosystems, both through payments for carbon sequestration and through co-benefits for production and climate change adaptation. As Lipper, *et al.* (2008) noted, while payments for carbon sequestration in rangelands are currently limited to voluntary carbon markets, negotiations on future global climate change agreements as well as emerging domestic legislation in several developed countries may soon increase the demand for emission reductions from rangeland management activities in developing countries.

Climate Change Adaptation and Associated Multiple Benefits

The potential consequences of climate change on vulnerable communities are becoming all too apparent. With or without climate change influences, there are still relentless challenges related to food security, poverty and ecosystem health. At the time of writing, the world's hungry had topped 1 billion people. During a review of opportunities and challenges for mitigation in the agricultural sector by the Ad Hoc Working Group on Long-term Cooperative Action (AWG-LCA) under the UNFCCC in 2009, Parties noted the synergy among mitigation in agriculture, adaptation, sustainable development, food security, poverty alleviation and energy security, and stressed the need to address the interlinked issues of mitigation and adaptation simultaneously (UNFCCC/AWGLCA, 2009). Climate change may thus serve as a driver for implementation of sustainable land management for both mitigation and adaptation, while also providing pathways to meet the actions called for in the context of UNCBD and UNCCD, and for enhancing sustainable and enhanced productivity to address hunger.

The capacity of a system (social or biophysical) to adjust to climate change includes adaptive coping mechanisms as well as adaptive strategies (IPCC, 2007). These adjustments, intended to reduce vulnerability to climate change, vary among regions and socio-economic groups (Kates, 2000). Notwithstanding the influence of climate

BOX 2

East African pastoralist strategies

East African pastoralists use a diversity of strategies to sustain production. This is important for their own livelihoods but also for their national economies, in terms of providing a large share of livestock for markets in the region and coping with climate variability. These strategies include moving livestock according to vegetation needs and water availability, keeping species-specific herds to take advantage of the heterogeneous nature of the environment, diversifying their livelihood strategies and, in some cases, temporary or permanent emigration (Galvin, 1992; Galvin, *et al.*, 1994).

However, current constraints to these traditional strategies have made pastoralists more vulnerable to natural and human-derived perturbations. Population pressure and many land-tenure and land-use changes have squeezed pastoral livestock onto land areas that are too small to be sustainable for pastoral production. Pastoralists no longer can depend on their livestock as the sole basis of their livelihoods, yet have few opportunities for livelihood diversification.

Although these pastoralists have been able to track climate variability very well in the past, based on centuries of exposure to intra- and inter-annual droughts as well as floods, their strategies are not working now due, in part, to an inability to implement them. Furthermore, it is likely that the nature of the climate variability that pastoralists deal with will itself change, adding new variability to the system (IPCC, 2001). Specific cases in Malawi and elsewhere have shown the need to help pastoralists develop new adaptation strategies based on traditional farming systems and alternative sources of income, and backed by enabling policies.

change and despite the constraints imposed by policies and institutions, communities have historically demonstrated their capacities to change their practices in the drylands in order to maintain production and livelihoods (see Box 2).

Mitigation efforts also can enhance adaptation strategies. Environmental co-benefits resulting from increased carbon sequestration can increase agro-ecosystem resilience and decrease vulnerability to disasters and climate variability (FAO, 2009). In fact, the policy-driven divide between adaptation and mitigation may blur as some adaptation strategies also serve to mitigate climate change and vice versa.

It has been demonstrated that grassland management practices that enhance soil C sequestration can result in greater biodiversity, improved water management with respect to both quantity (reduced run-off and evaporation or improved flood control) and quality (reduced or diffused pollution of waterways), and restoration of land degradation. Further, these same practices enhance productivity and food security and can perhaps lend themselves to offsetting potential conflicts over dwindling resources. Most grasslands also serve as important catchment areas and good management practices accrue benefits to communities outside of grasslands. Yet they must be managed by the livestock keepers (FAO, 2005).

Rapid reviews of the National Adaptation Programmes of Action (NAPA) received by the UNFCCC include several examples of adaptation strategies that also can increase carbon sequestration.[1] For example, Ethiopia's NAPA proposes actions that restrict free grazing (overgrazing), support rotational grazing, and improve and enhance rangeland resources in pastoral areas. Eritrea's NAPA prioritizes the implementation of community-based rehabilitation of rangelands, improving livestock productivity, and adaptation of species and breeds to climatic variability. Grazing management activities that may sequester carbon also figure prominently in adaptation plans in other pastoral societies such as Mongolia (Batima, *et al.*, 2006). It should be noted, however, that some analyses of climate change impacts and prioritized adaptation actions in the national policy frameworks of some countries have not considered the full rationality and ecosystem management potential of extensive grazing. This risks further constraining pastoralists' abilities to manage livestock and rangelands in order to maximize mitigation and adaptation synergies. Inappropriate policies can contribute either to decreased adaptive capacity or to increased vulnerability (Finan and Nelson, 2001; Little, *et al*., 2001).

In a recent workshop on Securing Peace, Promoting Trade and Adapting to Climate Change in Africa's Drylands, DfID (2009) illustrated that pastoral institutions and production strategies are potentially better adapted to respond to increased climate variability than other land-use systems and provide higher net returns and flexibility under conditions of variability. Further, livelihoods such as pastoralism, which span a broader geographical domain through migration, are likely to be more resilient than sedenterized livelihoods. Where climate change increases precipitation in dry land areas, increasing suitability for crop production may bring conflict with traditional users of grazing lands.

The multiple benefits of adaptive and mitigative measures that address climate change and enhance livelihoods, ecosystem services and food security must be at the front and

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[1] Submitted NAPAs can be viewed at http://unfccc.int/cooperation_support/least_developed_countries_portal/napa_project_database/items/4583.php

PHOTO 7
Herrero pastoralists (Namibia)

center of the climate change response and the preventive measures and polices that support them. While grasslands are clearly not at the center of current global climate negotiations, they are important and deserve more emphasis. In addition to their mitigation potential, grasslands (including agroforestry and rangeland systems) play a significant role in human and environmental health and, if not adequately addressed, will have potentially dramatic consequences for food security, environmental degradation and livelihoods (FAO, 2009).

Key Messages

Our environmental crises are inter-related. Climate change, biodiversity loss, drought and desertification are inter-related symptoms of unsustainable land management. They result in loss of agricultural productivity, reduced capacity to sustain rural livelihoods and increased risk of, and vulnerability to, natural and human disasters. Refocusing efforts and investment on management for healthy productive land and improved tenure security are a prerequisite to securing the lives and livelihoods of millions of people worldwide and to sustaining the range of products and services provided by the environment in the short and long term.

Livestock are an irreplaceable source of livelihoods for the poor. Livestock is the fastest growing agricultural sector, and in some countries accounts for 80 percent of GDP, in particular in drylands. Of the 880 million rural poor people living on less than USD 1.00 per day, 70 percent are at least partially dependent on livestock for their livelihoods and subsequent food security (World Bank, 2007). Grasslands – the basis for livestock production – cover some 70 percent of the global agricultural area.

Drylands occupy 41 percent of the earth's land area, their adapted management can sustain livelihoods of millions of people, and they both contribute to and mitigate climate change. Drylands are home to more than 2 billion people with some two thirds of the global dryland area used for livestock production (Clay, 2004). In sub-Saharan Africa, 40 percent of the land area is dedicated to pastoralism (IRIN 2007). However, desertification and land degradation in the drylands are reducing the capacity of the land to sustain livelihoods. Moreover, degradation processes reduces the possibility of capturing and retaining water and sequestering carbon, resulting in carbon being released into the atmosphere. Worldwide, some 12–18 billion tonnes of carbon already have been lost as a result of desertification. There is, however, a huge potential for sequestration of carbon in dryland ecosystems. Appropriate management practices could continue to support millions of (agro-) pastoral peoples and also sequester an estimated 1 billion tonnes C per year (Lal, 2004).

Grasslands, by their extensive nature, hold enormous potential to serve as one of the greatest terrestrial sinks for carbon. The restoration of grasslands and good grazing land management globally can store between 100 and 800 Mt CO_2-eq per year for inputs ranging from USD 20 to 100, respectively (IPCC 2007). Smith, *et al.* (2008) have estimated that improved rangeland management has the biophysical potential to sequester 1.3- 2.0 Gt CO2e worldwide to 2030. Well-managed grasslands can store up to 260 tonnes of carbon per ha while providing important benefits for climate change adaptation (FAO 2007). Global grasslands store a total of between 1 752– 2 385 Gt of carbon, 71 percent of which is below the soil surface (White, *et al.*, 2000). Appropriate management of grasslands to prevent further degradation – especially in currently non-degraded grassland areas – will make a significant contribution to mitigating future climate change.

Appropriate grassland management practices contribute to adaptation and mitigation, as well as increasing productivity and food security and reducing risk of drought and flooding. Well-managed grasslands provide many co-benefits that are critical to adaptation. Risks associated with prolonged drought periods and unreliable rains can be offset by the increased water infiltration and retention associated with organic matter accumulation in the soil. Moreover, this will improve nutrient cycling and plant productivity and, at the same time, enhance the conservation and sustainable use of habitat and species diversity. Grassland management is thereby a key adaptation and mitigation strategy for addressing climate change and variability.

Livestock play an important role in carbon sequestration through improved pasture and rangeland management (FAO/LEAD, 2006). Good grassland management includes managed grazing within equilibrium and non-equilibrium systems and requires: 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 (Jones 2006), and d) understanding impacts of and adapting to climate change, e.g. plant community changes. Grassland productivity is dependent on the mobility of livestock (Niamir-Fuller, 1999).

Enabling grassland and livestock stewards to manage the vast grassland for both productivity and carbon sequestration requires a global coordinated effort to overcome socio-political and economic barriers. The key barriers include: land tenure, common property and privatization issues; competition from cropping including biofuels and other land uses which limit grazing patterns and areas; lack of education and health services for mobile pastoralists; and policies that focus on reducing livestock numbers rather than grazing management.

Assessing the biophysical, economic and institutional potential of supporting pastoralists' access to global carbon markets requires a concerted effort. Carbon sequestration in grasslands and rangelands has been excluded from existing international carbon trading mechanisms such as CDM because of perceived limitations around measurement and monitoring due to soil variability and because of perceived risks of non-permanence of sequestered carbon. Since the CDM was initially designed, scientific understanding of grassland carbon cycles and management impacts has progressed. More recently, with support from voluntary carbon markets, there have been efforts to demonstrate ways to overcome perceived barriers, through the development of tools and methods for rapid carbon assessments and ex-ante project mitigation evaluation, and through development of widely credible standards for verifying additional and permanent emission reductions under diverse land use types and agro-ecological zones. It is also increasingly recognized that land use mitigation options also have significant adaptation benefits.

Healthy grasslands, livestock and associated livelihoods constitute a win-win option for addressing climate change in fragile dryland areas where pastoralism remains the most rational strategy for maintaining the wellbeing of communities. Despite increasing vulnerability, pastoralism is unique in simultaneously being able to secure livelihoods, conserve ecosystem services, promote wildlife conservation and honour cultural values and traditions (ILRI 2006, UNDP 2006). Pastoral and agropastoral systems provide a win-win scenario for sequestering carbon, reversing environmental degradation and improving the health, well-being and long-term sustainability of livestock based livelihoods. Ruminants convert vast renewable resources from grasslands that are not otherwise consumed by humans into human edible food.

The Way Forward

Greater recognition and support is needed for sustainable pastoral and agropastoral systems in view of their contributions to climate change adaptation and mitigation, disaster risk management and sustainable agriculture and rural development. Targeted support by governments, civil society organizations, development agencies and community donors, (agro)-pastoral networks, development practitioners and researchers is needed to harness this opportunity through the following.

- *Raising awareness* that improved land management in grasslands and rangelands in drylands offers the opportunity for soil and above-ground carbon sequestration and adaptation to climate change and variability while enhancing livestock productivity and food security.

- *Documenting, compiling and disseminating* available information on carbon sequestration potential in grasslands and rangelands and *building capacity* in simple tools and methods for accounting of carbon emissions and removals from pastoral lands.

- *Providing incentives,* including payments for environmental services (PES) and other non-financial rewards, voluntary and regulatory arrangements in order to support a change in behaviour towards sustainable and adapted management of these fragile ecosystems. These incentive mechanisms should capitalize on the synergies of increased C stocks, sustainable use of biodiversity and reversing land degradation, all of which serve to enhance livelihoods and reduce vulnerability of pastoral and agropastoral peoples.

- *Establishing pro-poor livestock policies* that address the barriers and bottlenecks faced by (agro-) pastoral peoples, *and supporting a paradigm shift* to build local- and policy-level awareness and capacity for good grassland management and secure tenure at community and landscape levels.

- *Conducting targeted research* in undervalued natural grasslands and livestock-based ecosystems, facilitating methods for measurement, monitoring and verification of C sequestration related to different management practices, ensuring full GHG accounting and generating improved understanding of the economic and institutional aspects of carbon sequestration involving smallholders.

- *Promoting integrated multi-sectoral, multi-stakeholder and multi-level processes* that address the range of natural resources (land, water, rangelands, forests, livestock, energy, biodiversity) and social dimensions with active involvement by all concerned actors. These holistic approaches and partnership processes must take advantage of win-win options among local, national and global goals.

- *Supporting adaptation to climate change and climate variability among livestock keepers*, including bringing existing traditional as well as modern technical, management and institutional options into play, and seeking consistency between climate change adaptation policies and pro-poor policies that support a vibrant and sustainable pastoral sector at local, regional and national levels.

- *Enhancing capacity* to draw on the range of available development and funding mechanisms for addressing poverty alleviation (in line with the MDG targets), desertification, drought and loss of biodiversity (for instance through Global Environment Facility, Operational Programme #15 on sustainable land management). It is necessary to focus on existing and future mechanisms for climate change adaptation, in order to effectively catalyse and sustain required investments and actions in sustainable livestock-based systems and the vast areas of pasture and rangeland systems worldwide.

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