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CHAPTER XIII

Managing dryland pastoral systems: implications for mitigation and adaptation to climate change[1]

Abstract

In light of global concerns over the multiple impacts of climate change and climate variability, this chapter makes a case for a concerted global effort to promote mitigation practices that also have benefits for the adaptation and livelihoods of pastoralists and agropastoralists in drylands. The document highlights the importance of drylands, grazing lands and livestock-based livelihoods and illustrates the interrelations between climate change, biodiversity loss, desertification and drought in these systems. Building on estimates of the potential carbon (C) storage and sequestration in pasture and rangelands in drylands, the paper outlines the main land management measures for improving C cycling and grassland management while recognizing the socio-economic dimensions of rangeland management and the climate change adaptation and associated co-benefits. In conclusion, it presents some key messages on the importance of grasslands and rangelands in terms of their contribution to C 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.

[1] An extended version of this paper, entitled *Review of evidence on dryland pastoral systems and climate change: implications and opportunities for mitigation and adaptation*, can be found in FAO Land and Water Discussion Paper 8, 2009.

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 (C) in soils while supporting sustainable pastoral and agropastoral livelihoods for millions of people.

Soils represent the Earth's largest terrestrial C sink that can be controlled and improved, and grassland management has been cited as the second most important agricultural technology available for climate change mitigation. This chapter argues that livestock and pastoral systems have a major role to play in climate change mitigation and, perhaps more important, 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 one 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 USD1.00/day.

Degradation of the land base negatively affects the accumulation of C in the soils. Thus, reversing land degradation in extensive dryland areas through improved pasture and rangeland management would contribute to restoring the soil C sink while improving soil health, enhancing productivity, reducing risks to drought and flood and improving livestock-based livelihoods. Soil C sequestration in dryland grazing areas offers multiple benefits for enhancing ecosystem services.

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 sociopolitical and economic barriers, such as land tenure constraints and inadequate services for, and political marginalization of, pastoral and agropastoral communities.

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 of its agricultural lands (FAO, 2005a; WRI, 2000; White, Murray and Rohweder, 2000). Drylands occupy 41 percent of the land area and are home to more than two billion people (UNEP, 2006). Of the 3.4 billion ha of rangelands worldwide, an estimated 73 percent are affected by soil degradation (WOCAT, 2009).

It is estimated that over one billion people depend on livestock, and 70 percent of the 880 million rural poor living on less than USD1.00/day are at least partially dependent on livestock for their livelihoods (World Bank, 2007a). Livestock production can be found on two-thirds of global drylands (Clay, 2004). Extensive pastoralism occurs on a quarter of the global land area and supports around 200 million pastoral households (Nori, Switzer and Crawford, 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 its daily livelihoods (CBD/UNEP/IUCN, 2007). 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).

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, 2007a). Livestock are socially and economically critical to rural livelihoods, thus giving high priority to ensuring the sustainable use of the natural resource base that supports them. 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).

While rangelands are often and erroneously considered "marginal" terrain, in reality, dryland species and ecosystems have 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). Rangelands are essential to the subsistence of pastoralists and agropastoralists and, moreover, with the warming and drying influence of climate change, it is anticipated that in the coming decades livestock may provide an alternative to crop production, particularly in Africa (Jones and Thornton, 2008).

CLIMATE CHANGE, LAND AND LIVESTOCK INTERRELATIONSHIPS

Climate change is expected to cause global average surface temperature to increase some 1 to 2.5 °C by 2030 and 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 will also 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 carbon dioxide equivalent (CO_2eq) emissions (IPPC, 2007b), 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 (C) and up to 60 percent loss of below-ground C (Reid *et al*., 2004; Guo and Gifford, 2002). Degradation of above-ground vegetation can cause an estimated loss of 6 tonnes C/ha and soil degradation processes lead to a loss of 13 tonnes C/ha (Woomer, Toure and Sall, 2004).

Although agriculture is viewed as a major source of greenhouse gas (GHG) emissions, it holds great potential to contribute to mitigation, through actions to reduce GHG emissions (CO_2, methane [CH_4], nitrous oxide [N_2O]) and to enhance C sinks, particularly through soil C sequestration (IPCC, 2007a). It is estimated that improved grassland management and restoring degraded soils together have the potential to sequester around 2 000 tonnes CO_2eq/year by 2030 (Smith *et al.,* 2008), and in extensive grazing systems these figures are estimated to offset the livestock-related emissions.

The impacts of climate change on productivity and sequestration potential are likely to be highly spatially variable and dependent on location, management system and species, but developing countries, mainly in Africa, are generally considered more vulnerable than developed countries because of 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. Climate change and variability will have serious implications, impacting on ecosystems goods and services on which poor people and livestock keepers depend, thus exacerbating current development challenges. In semi-arid rangelands where shorter growing seasons are likely, rangeland productivity may decrease; however, in East and southern Africa, livestock may become the more appropriate food and income source as croplands become more marginal (Thornton *et al.*, 2008; Jones and Thornton, 2008).

Agricultural and land-based mitigation measures can provide benefits to productivity and livelihoods and contribute to climate change adaptation by reducing risks for vulnerable people and their ecosystems. These co-benefits or "win–win options" warrant greater attention than they have received to date.

Soil C 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 United Nations conventions (Lal, 2004b). Co-benefits of C sequestration may also 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 drylands are particularly sensitive to land degradation, with 10–20 percent of drylands already degraded (Millennium Ecosystem Assessment, 2005). 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 eight percent of degradation found in the dry subhumid regions, nine percent in the semi-arid regions, and five percent in arid and hyper-arid regions.[2]

Up to 71 percent of the world's grasslands were reported to be degraded to some extent in 1991 (Dregne, Kassa and Rzanov, 1991) as a result of poor land management that led to overgrazing, salinization, alkalinization,

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

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 caused by 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, Janzen and Herrick, 2002). A wide range of management practices including grazing, fire and fertilization practices as well as conversion of grasslands into croplands can affect soil C storage in rangelands (Conant, Paustian and Elliott, 2001; Schuman, Janzen and Herrick, 2002).

Worldwide, some 18–28 billion tonnes of C are estimated to have been lost as a result of desertification (i.e. land degradation in drylands), and grazing-induced desertification in the drylands has been estimated to emit as much as 100 million tonnes of CO_2/year (FAO/LEAD, 2006). Degradation of dryland soils means that they are far from saturated and thus potentially have a significant capacity to store more C (Farage, Pretty and Ball, 2003). The technical potential of C sequestration through desertification control and restoration has been estimated at 12–18 billion tonnes of C over a 50-year period (Lal, 2001 & 2004b).

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 last longer. 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. Impacts are already being reported (Guha-Sapir *et al*., 2004).

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. Increasing the amount of C sequestered as soil organic matter (SOM) can enhance rainfall effectiveness through increased infiltration and water-holding capacity and water source replenishment to withstand times of drought better. Carreker *et al.* (1977) demonstrated the direct relationship between soil organic carbon (SOC) and infiltration and the amount of time taken for water to run off the land in a rainfall event. Thurow, Blackburn and Taylor (1988) showed that infiltration was directly related to percentage of ground cover. Reduction or loss of surface vegetative cover is a critical factor as it results in accelerated runoff and erosion, which increase the severity and extent of degradation and further reduce 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 behaviour 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 the low levels of diversity currently recorded in many of the world's rangelands are 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, because of 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 regraze plants before adequate recovery – and by land degradation that causes changes in species composition and intraspecies competition. This is exemplified by bush encroachment, 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 (unsustainable) livestock management as one of the threats to as many as 1 700 endangered species (FAO/LEAD, 2006).

As land conversion is a major source of CO_2 emissions, it is also a main cause of biodiversity loss. For example, of the 13 million ha of forest lost annually (FAO, 2005a), land cleared for livestock accounts for some 1.5 million ha/year (De Haan *et al.*, 2001), resulting in severe loss of habitat and species. 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 use different species and traditional breeds and have developed very resilient grazing systems that manage to maintain relatively high human populations on rangelands of low and highly variable productivity and allow for adaptation to harsh environments.

Extirpation of native grazers, habitat fragmentation, increased nitrogen (N) deposition from the atmosphere and altered fire frequency are major causes of disruption in grassland ecosystems worldwide (WRI, 2000). 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 the 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 CH_4 emissions and 65 percent of N_2O emissions (FAO, 2006; 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/year (FAO/LEAD, 2006). Of the total CH_4 emissions from enteric fermentation, grazing systems contribute some 35 percent compared with 64 percent for mixed farming systems (FAO/LEAD, 2006).

IPCC (2007b) has reported that pasture quality improvement can be important in reducing CH_4, 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' C sequestration (discussed later in this chapter) is considered significantly higher than methane emissions resulting from enteric fermentation or manure management. Land degradation from overgrazing of plants decreases reabsorption of atmospheric CO_2 by vegetation regrowth (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 of plants and resulting soil and vegetation degradation in order to enhance C 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 will also 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 urban and better-off populations. In sub-Saharan Africa, growing consumption is anticipated to be 30 percent for meat and 14 percent for milk between 1999 and 2030 (WHO/FAO, 2002).

Fire

Annual burning of tropical grasslands plays a significant role in the global C cycle. The C associated with biomass burning is staggering. The amount of C released just by burning grasslands worldwide is estimated at 1.6 Gt C/year (Andreae, 1991; Andreae and Warneck, 1994). 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 forests. Large areas of savannah in the humid and subhumid tropics are burned every year for rangeland management, totalling some 700 million ha worldwide. This is especially severe in Africa where about 75 percent of grasslands are burned annually (FAO/LEAD, 2006).

Biomass burning in the savannahs destroys vast quantities of dry matter per year and contributes 42 percent of gross C dioxide to global emissions (Levine *et al,* 1999; Andreae, 1991). This is three times more than the CO_2 released from burning rain forests. 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 regrowth. In savannah systems that contain woody species, it has been shown that the C 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 SOC in the upper few centimetres of soil (Vagen, Lal and Singh, 2005) as well as reducing soil water retention capacity, killing micro-organisms in the surface soil and reducing their food substrate, exposing the soil to erosion and, in some soils, increasing soil surface hardness (NARO; IDRC; CABI, n.d.).

CARBON STORAGE AND POTENTIAL SEQUESTRATION

While C storage in grasslands is less per unit area than forests, the total amount of C that grasslands store is significant because the area of these ecosystems is so extensive (White, Murray and Rohweder, 2000) Estimates of C storage for each dryland region indicate that 36 percent of total C storage worldwide is in the drylands, and 59 percent of the total C stock held in Africa is in the drylands (Campbell *et al*., 2008; UNEP, 2008).

There is a great potential for C sequestration in drylands because of their large extent and because substantial historic C losses mean that drylands soils are now far from saturation (FAO/LEAD, 2006). Lal (2004b) estimates that soil C sequestration in the dryland ecosystems could achieve about one billion tonnes C/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 to sequester 1.3–2 Gt CO_2eq worldwide to 2030. Potential sequestration for Australian rangelands is estimated at 70 million tonnes of C/year (FAO/LEAD, 2006).

The scope for SOC gains from improved management and restoration within degraded and non-degraded croplands and grasslands in Africa is estimated at 20–43 Tg C/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 C sequestration for up to 50 years (Lal *et al.*, 1998; Conant, Paustian and Elliott, 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 C sink capacity of the world's agricultural and degraded soils is said to be 50–66 percent of the historic C loss from soils, or some 42–78 Gt of C (Lal, 2004b). Restoring land health on large areas of degraded land could thus compensate for significant amounts of global C emissions. Although many of the grassland areas in drylands are poorly managed and degraded, it also follows that they offer potential for C 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 the establishment of natural or improved fallow systems (agroforestry and managed resting of land for plant recovery) with attainable rates of C sequestration in the range of 0.1–5.3 Mg C/ha/year. Fallow systems generally have the highest potential for SOC sequestration in sub-Saharan Africa, with rates up to 28.5 Tg C/year (Vagen, Lal and Singh, 2005).

To date there has been little documentation of implementation and opportunity costs of uptake of C 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 C stocks of 1 328 million tonnes C/year for some 25 years. This would overshadow the concomitant emissions related to livestock in all of Africa (FAO/LEAD, 2006).

Improved grazing land management may prove to be a cost-effective method for C sequestration, particularly taking into account the side benefits of soil improvement and restoration and related social and economic benefits for livestock keepers.

Improving management practices

Since grazing is the largest anthropogenic land use, improved rangeland management could potentially sequester more C 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 C sequestration and storage (Schuman, Janzen and Herrick, 2002).

Conant, Paustian and Elliott (2001) reviewed 115 published studies on the impacts of specific management practices on soil C sequestration in rangelands globally and found that on average, management improvements and conversion into pasture lead to increased soil C content and to net soil C storage. Proper grazing management has been estimated to increase soil C storage on rangelands in the United States from 0.1 to 0.3 Mg C/ha/year and new grasslands have been shown to sequester as much as 0.6 Mg C/ha/year (Schuman, Janzen and Herrick, 2002). Drawing on a global database, Conant, Paustian and Elliott (2001) found that improved grazing can sequester from 0.11 to 3.04 Mg C/ha/year, with an average of 0.54 Mg C/ha/year. Since C 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/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/year through cessation of overgrazing, although research has also found that some grasslands sequester more C in response to heavier grazing intensities. Reeder and Schuman (2002) reported higher soil C levels in grazed – compared with ungrazed – pastures, and noted that when animals were excluded, C 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 C was both increased (60 percent of cases) and decreased (40 percent of cases). In the northwestern United Republic of Tanzania some 500 000 ha of degraded lands have been recovered through agro-silvopastoral practices, including a combination of woodlots, fodder banks, alley and mixed cropping, boundary and tree plantings and natural revegetation resulting in 1.7 to 2.4 tonnes/ha of C sequestration (Rubanza *et al.*, 2009).

IPCC (2007b) reported several measures to improve grasslands in light of mitigation and C 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) reported 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 C 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 C 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 C and N emissions associated with the adoption of improved management practices must be considered when estimating the C sequestration potential of grassland soils with improved management.

IMPROVING CARBON CYCLING AND GRASSLAND MANAGEMENT

Soil C stems from SOM and, as Lal (2004b) 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. 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, 2004b) and thus well-managed grasslands can provide mitigation and adaptation benefits.

Jones (2006a) 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 up the C pool.

Elements of good grassland and grazing management

In defining good grazing management, Jones (2006a) 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 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.

(i) Grazing lands evolved from a historical predator-prey relationship, with pack-hunting predators keeping large herds of ungulates bunched and moving (McNaughton, 1979). Healthy grasslands are still achieved in drylands by bunching the stock into large herds and moving it frequently. Controlled grazing allows for more even distribution of dung and urine that can enhance SOM and nutrients for plant productivity thus simultaneously regenerating grasslands and improving livestock production.

(ii) 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 will often lead to desertification and loss of biodiversity in all but high rainfall areas (Jones, 2006a). In medium-to-low rainfall areas, grasses that 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 regrazed, 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).

(iii) 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, planned grazing can be practised 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, Blackburn and Taylor (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 six-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 adaptive planning – the use of guidelines and principles in a continuous iterative process instead of prescripts such as uniform stocking rate prescriptions. Monitoring of livestock productivity and range conditions and productivity, and learning lessons from experience and practice can provide the framework that will allow an appropriate response to a wide range of circumstances.

Research by Rowntree *et al.* (2004) supports ecologists' contention that communal grazing systems do not necessarily degrade range conditions 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 vigour 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 C storage in grassland sites is the high C 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 N-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 ('t Mannetje *et al.*, 2008). Thus, one of the most effective strategies for sequestering C is fostering deep-rooted plant species. It has also been shown that native species in grazing lands can increase C accumulation while enhancing biodiversity (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, Scoones and Kerven, 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, Scoones and Kerven, 1993; Scoones, 1994). Nori (2007) argues that the mobility and flexibility of pastoral systems enable them to make the best use of the patchy and fragile environment. When compared with ranching models, pastoral systems are found to be more productive per unit area because of 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, Switzer and Crawford, 2005). Many exist in persistent states of crisis resulting from 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.

There are several cooperative efforts to enhance the voice of pastoralist groups. For example, the Segovia Declaration was put forward at the UN Convention to Combat Desertification (UNCCD) 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 them in reducing the impact of drought and climate change. Because biofuel production increasingly targets marginal farmlands, pastoralists have been identified as particularly vulnerable to losing access to essential grazing lands (Cotula, Dyer and Vermeulen, 2008).

Key constraints stemming from marginalization, 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.

Socio-economic issues in pastoralists' access to carbon markets

Within the context of international C markets, there must be clear tenure rights over land enrolled in C 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 landowners are unable to exclude others from the use of rangelands, it will be difficult to ensure that recommended C 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 C sequestration projects in such contexts will need to facilitate multistakeholder negotiation and conflict management, while protecting the interests of minorities and marginalized groups. Tennigkeit and Wilkes (2008) evaluated the potential for C finance in rangelands and also stressed that tenure issues are likely to be the main constraint on pastoralists accessing C markets.

In reviewing West African rangelands' potential for sequestering C, Lipper, Dutilly-Diane and McCarthy (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 C 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 C, C markets may not be able to support implementation of C sequestrating management practices in the absence of external cofinancing.

Strengthening rural institutions and securing resource tenure are key elements of a sustainable and equitable C sequestration strategy.

The economic feasibility of C sequestration in grasslands also depends on the price of C. IPCC (2007b) notes that at USD20/tonnes CO_2eq, grazing land management and restoration of degraded lands have potential to sequester around 300 Mt CO_2eq up to 2030; at USD100/tonnes CO_2eq they have the potential to sequester around 1 400 Mt CO_2eq over the same period. These potentials put grassland C sequestration into the category of "low cost" and readily available mitigation practices. A study of mitigation options in China (Joerss, Woetzel and Zhang, 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), analysing 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, C sequestration programmes have the potential to provide economic benefits to households in degraded dryland ecosystems, both through payments for C sequestration and through co-benefits for production and climate change adaptation. As Lipper, Dutilly-Diane and McCarthy (2008) noted, while payments for C sequestration in rangelands are currently limited to voluntary C 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 one billion people. Climate change may 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 the United Nations Convention on Biological Diversity (UNCBD) and UNCCD, and for enhancing sustainable and consistent productivity to address hunger.

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

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 runoff and evaporation or flood control) and quality (reduced or diffused pollution of waterways), and restoration of land degradation. Furthermore, 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 grasslands. Yet they must be managed by the livestock keepers (FAO, 2005a).

Rapid reviews of the National Adaptation Programmes of Action (NAPAs) received by the UNFCCC include several examples of adaptation strategies that can also increase C sequestration.[3] 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, Department for International Development (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. 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 centre of the climate change response and the preventive measures

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

and polices that support them. While grasslands are clearly not at the centre of current global climate negotiations, they are important and will continue to deserve greater emphasis.

KEY MESSAGES

Our environmental crises are interrelated

Climate change, biodiversity loss, drought and desertification are interrelated 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 are the fastest growing agricultural sector, and in some countries account for 80 percent of GDP, particularly in drylands. Of the 880 million rural poor people living on less than USD1.00/day, 70 percent are at least partially dependent on livestock for their livelihoods and subsequent food security (World Bank, 2007a & b).

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. Worldwide, some 12–18 billion tonnes of C have already been lost as a result of desertification. There is, however, a great potential for sequestration of C in dryland ecosystems. Appropriate management practices could continue to support millions of (agro)pastoral peoples and also sequester an estimated one billion tonnes of C/year (Lal, 2004a).

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_2eq/year for inputs ranging from USD20 to 100, respectively (IPCC, 2007b). Smith *et al.* (2008) have estimated that improved rangeland management has the biophysical potential to sequester 1.3–2.0 Gt CO_2eq worldwide to 2030. Well-managed grasslands can store up to 260 tonnes of C/ha while providing important benefits for climate change adaptation. (FAO, 2001).

Appropriate grassland management practices contribute to adaptation and mitigation, as well as increasing productivity and food security and reducing risks 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.

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: (i) understanding of how to use grazing to stimulate grasses for vigorous growth and healthy root systems; (ii) 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; (iii) providing adequate rest from grazing without over-resting the plants (Jones, 2006); and (iv) 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 grasslands for both productivity and carbon sequestration requires a global coordinated effort to overcome sociopolitical and economic barriers

The key barriers include land tenure, common property and privatization issues; competition from cropping, including biofuels and other land uses that 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 (formal) international C trading mechanisms such as the Clean Development Mechanism (CDM) because of perceived limitations around measurement and monitoring resulting from soil variability and because of perceived risks of non-permanence of sequestered C. Since the CDM was initially designed, scientific understanding of grassland C cycles and management impacts has progressed. More recently, with support from voluntary C markets, there have been efforts to demonstrate ways to overcome perceived barriers, through the development of tools and methods for rapid C 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. Furthermore, it is 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 well-being 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 C, 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 edible human food.

LOOKING FORWARD

Greater recognition and support are 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 aboveground C sequestration and adaptation to climate change and variability while enhancing livestock productivity and food security.
- *Documenting, compiling and disseminating* available information on C sequestration potential in grasslands and rangelands and *building capacity* in simple tools and methods for accounting of C 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 the 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 C sequestration involving smallholders.

- *Promoting integrated multisectoral, multistakeholder and multilevel 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 No. 15 on sustainable land management). It is necessary to focus on existing and future mechanisms for climate change adaptation, in order to catalyse and sustain required investments and actions in sustainable livestock-based systems effectively and the vast areas of pasture and rangeland systems worldwide.

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