Working Paper

An Assessment of the Potential for Carbon Finance in Rangelands

Timm Tennigkeit and Andreas Wilkes

Southeast Asia

World Agroforestry Centre
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Abbreviations and units of measurement

AFOLU Agriculture, forestry and other land use
C carbon
CCX Chicago Climate Exchange
CDM Clean Development Mechanism
CF Carbon finance
ERs Emissions Reductions
GEF Global Environment Facility
GHG Greenhouse gases
Gt 1,000,000,000 (1 billion) metric tonnes
ha Hectare
IPCC Intergovernmental Panel on Climate Change
IUCN International Union for Conservation of Nature
Mha mega hectare (1 million hectares)
NAP National Allocation Plan
NPV Net Present Value
OECD Organization for Economic Co-operation and Development
PES Payments for Ecosystem Services
SOC Soil Organic Carbon
tC metric tonnes of carbon
tCO2e tonnes of carbon dioxide equivalent (1tC = 3.667 tCO2e; 1 tCO2e = 0.273 tC)
UNFCCC United Nations Framework Convention on Climate Change
VCS Voluntary Carbon Standard
WISP World Initiative for Sustainable Pastoralism
For a glossary of terms see http://carbonfinance.org/Router.cfm?Page=Glossary

Summary

Globally there are more than 120 million pastoralists who are custodians of more than 5000 M ha of rangelands, which store up to 30% of the world's soil carbon. Many pastoralists are poor. In 2007 carbon markets made transactions worth more than US$64 billion. The best available estimates suggest that improved rangeland management has a biophysical potential to sequester 1300-2000 MtCO2e worldwide up to 2030. This study examines the role that pastoralism can play in the sequestration of carbon, and assesses the feasibility of accessing carbon markets to support sustainable resource use and livelihood development among pastoralists.

Carbon market eligibility: At present rangeland management activities (except afforestation and reforestation) are not eligible under the CDM and most pre-compliance carbon trading systems. Currently, the only purchasers of rangeland carbon credits are in the voluntary market. Unless rangeland carbon credits can be used to meet compliance targets, demand will remain limited. Currently, only the Chicago Climate Exchange has a standard for accounting for emissions reductions from rangeland management activities. For other standards, such as the Voluntary Carbon Standard or CDM, the required methodologies have yet to be developed and approved. Existing experience from other land use related projects and standards could be drawn upon to develop a methodology for rangeland management activities. There is some interest in land use derived carbon credits among some private companies and carbon funds, driven partly by expectations that these carbon assets may fetch a premium price in the future. The main current constraints on entry of land use ERs into compliance markets are the risks that land-use based carbon sequestration may not be permanent, and methodological constraints. The 2007 UNFCCC Bali Declaration gave the green light to overcoming methodological issues preventing inclusion of a range of forestry activities in a post-2012 agreement. Some are also advocating for inclusion of all terrestrial carbon (including rangeland soil carbon) in a future climate change agreement.

Sequestration potential of rangeland management activities: In grassland ecosystems, the majority of carbon is stored in soils, so soil carbon sequestration is the main potential. Where shrubs and trees are present, they make a large contribution to total carbon stocks. Management practices that increase organic matter inputs to soils or that decrease losses from soil respiration and erosion can sequester additional carbon, while actions that decrease carbon inputs or increase losses should be avoided. Rangelands vary greatly in their climatic characteristics, vegetation and soil types. Research has established that some types of rangeland may respond positively to a certain practice, while the same practice may reduce sequestration rates elsewhere. Site-specific rangeland soil carbon management practices must be designed. The table below summarizes 304 published reports of the carbon sequestration effects of various management practices in diverse rangelands globally.

Carbon sequestration potential of rangeland management practices

Management practice	No. of data points*	Mean change in tCO_2e/ha/yr or total change in %C
Vegetation cultivation	c: 31 %: 7	9.39 tCO_2e/ha 0.56%
Avoided land cover / land use change	c: 65 %: 22	0.40 tCO_2e/ha 0.87%
Grazing management	c: 55 %: 21	2.16 t CO_2e/ha 0.13%
Fertilization	c: 27 %: 68	1.76 t CO_2e/ha 0.47%
Fie control	c: 2 %: 1	2.68 t CO_2e/ha 0%

*(c = no. of studies reporting in C content; % = no. of studies reporting in %C)

Economic feasibility: There is scant documentation of the costs of implementing improved rangeland carbon management practices. A small number of case studies suggests: (i) high initial costs may require subsidization; (ii) households with different capital and resource endowments will have different access to adoption of management practices and different potential to realise economic benefits; and (iii) payment incentives vary with the price per ton of CO_2.

Institutional feasibility: Rangelands are often in large contiguous areas, but this requires institutions to aggregate individual households' carbon assets. Herders associations or other NGOs could play roles in aggregating carbon assets and providing technical support for adoption of improved management practices. Carbon finance projects require a clear project boundary, clear tenure rights in national law (whether private or communal), and that rangeland owners can effectively exclude others from use. Where pastoralists lack formal land use rights, or where legal land rights exist but are not enforced, demonstrated potential for producing CF flows may potentially aid in pastoralists' lobbying for their land use rights.

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

The potential of carbon finance in rangelands: Because of global concern with climate change, it is expected that carbon markets will develop more rapidly and with deeper financial backing than other markets for ecosystem services. In the short-term it is more likely that charismatic rangeland carbon assets would be of interest to the voluntary market. Pilot projects and development of the necessary methodologies will generate important experiences for the compliance market and for sectoral approaches. Rangeland projects that meet the following criteria will be more likely to be developed into CF projects:

- Clear legal rights over rangelands
- Solid scientific documentation of C sequestration impacts of management practices
- Where adoption of these practices is in line with national sustainable development priorities and adaptation plans

● Where institutions involved have capacity to develop projects in accordance with common CF standards, and to support implementation.

Where these criteria are not met, they point to key areas required for capacity building in readiness for future CF market opportunities.

Constraints faced: The biggest constraint on the development of rangeland carbon finance is the exclusion of rangeland activities from eligibility in compliance markets. It remains to be seen whether a post-2012 international framework will create demand for a wider range of terrestrial carbon assets, including rangeland carbon. There are also important knowledge gaps regarding:

● Data to support realistic estimates of the global rangeland mitigation potential and estimation of the related project development and maintenance costs

● Understanding of interactions between climate change, carbon fluxes and management practices, and impacts on the permanence of carbon sequestration.

Recommendations:

※ **Capacity building in relation to a rangeland focused Trust Fund:** Costs for developing early rangeland CF projects and required methodologies will be high but development costs of subsequent projects will be much lower. This can justify public investment. Capacity building of stakeholders for engagement with carbon markets should be undertaken in interaction with sources of carbon finance, not as isolated training exercises. One successful approach is to establish a Trust Fund with the objective of developing a number of pilot projects focused on rangelands. The Trust Fund should be big enough to develop a cluster of projects in one region so as to facilitate close interaction between project developers and facilitate learning from available expertise.

※ **Raising the profile of rangeland sequestration potential in policy processes:** The importance of rangelands should receive better recognition in climate change mitigation and adaptation policy development processes at national and intergovernmental levels. Support for developing national GHG accounting systems for terrestrial carbon, including rangelands, would be required. These can set a baseline for prioritizing sources of mitigation and targeting the design of programmes to reward herders for mitigating CO_2 emissions at national or sub-national level.

※ **Improved availability of data:** Rangeland policy makers and managers in many countries, as well as key actors in the carbon finance sector, have relatively little awareness of the potential of rangeland carbon sequestration. Much existing data is not available in accessible forms. An updatable database should be created that provides practitioners and policy makers with state of the art knowledge on rangeland carbon sequestration practices, interactions with the climate change policy process and costs of implementation. Policy briefs identifying best practices can also be developed.

※ **Monitoring land rights issues:** Rangelands are often misunderstood as non-productive lands, and pastoralism seen as backward, of little economic value, and often also environmentally destructive. In this context, there is a risk that pastoralists' grazing rights are significantly altered in the framework of rangeland carbon finance projects. Therefore, equity issues have to be ensured in project design.

Contents

1. Introduction

1.1 Carbon Finance and Pastoralist Resource Management and Development

Globally there are more than 120 million pastoralists who are custodians of more than 5000 Mha of rangelands (White et al 2000), a significant proportion of whom live in income poverty. Pastoralist livelihoods are dependant on utilization of natural resources. Traditional resource management practices in many pastoralist societies enable sustainable use of rangeland resources (Barrow et al 2007). Driven by inappropriate rangeland management and development policies, the breakdown of traditional resource management regimes and cessation of beneficial rangeland management practices has often been a key cause of rangeland degradation (IPCC 2000). Nevertheless, pastoralists continue to be blamed in international policy circles for land degradation (e.g. Steinfeld et al. 2006).

Without remedial action, average global temperatures could reach 2ºC higher than pre-industrial levels by 2035-2050 (Stern 2007). Other changes of significance for pastoralism include changes in the length and timing of the growing season, changes in the amount and seasonal pattern of precipitation, and rising atmospheric CO_2 concentration (Hall et al 1995). Although pastoralist societies have made minimal contribution to the current rate of global warming, many pastoral areas will be severely affected by climate change, making resource management an important priority. Rangeland-based adaptation strategies – such as seasonal grassland reserves (Angassa and Oba 2007) or revival of traditional grazing systems and development of forage reserves (Batima 2006) – are likely to benefit vegetation and soil carbon sequestration, and have the potential to play roles in both adapting to and mitigating further climate change.

What role can pastoralism play in the sequestration of carbon and reduction in the rate of global climate change? Specifically, do pastoralists' land management practices promote the sequestration of carbon in rangeland soils and vegetation? These questions are especially pertinent given the development of carbon markets. In 2007, the Kyoto compliance market made transactions worth US$64 billion, while the voluntary market traded at least US$337 million (Capoor and Ambrosi 2008). The value of the carbon market will continue to grow rapidly in the coming years. Could these growing markets be accessed to support sustainable resource management in the world's rangelands while also supporting livelihood development for their pastoralist custodians?

Considering that rangelands cover about 40% of the world's land area (White et al 2000), and that the majority of the world's rangelands are degraded to some degree (Dregne and Tchou 1992), the carbon sequestration potential of sustainable land management in rangeland areas would appear initially to be huge. [1] A high-profile FAO-supported report made the following claims for C sequestration potential of drylands:

> *"Typical population densities in pastoral areas are 10 people per km^2 or 1 person per 10 ha. If carbon is valued at US$10 per tonne and modest improvements in management can gain 0.5 tonnes C/ha/yr, individuals might earn US$50 a year for sequestering carbon. About half of the pastoralists in Africa earn less than US$1 per day, or about US$360 per year. Thus, modest changes in management*

[1] For estimates of the C sequestration potential of global grasslands, see Lal (2004), Keller and Golstein (1998), Batjes (2004), Reid et al (2004).

could augment individual incomes by 15 percent, a substantial improvement (Reid et al. 2004). Carbon improvements might also be associated with increases in production creating a double benefit" (Steinfeld et al. 2006: 119)

Indeed, rangeland carbon finance projects have already begun transactions in the USA and Central America. Some other studies, though, have been less optimistic. Another FAO review of the C sequestration potential of dryland farming systems concluded:

> *"Given the results from the case studies, it can be concluded that substantial funds from development organizations or carbon investors will be necessary in order to make soil [carbon sequestration] projects in dryland small-scale farming systems a reality. The expected benefits are probably insufficient to compensate farmers for costs occurring at the local level" (FAO 2004: Ch 6).*

Given the positive claims and experiences, the potential for pastoralism to contribute to rangeland soil carbon deserves significant attention. At the same time, cautionary experiences suggest that careful attention must be paid to the conditions under which this potential can be realized.

1.2 Purpose and Scope of this Study

The purpose of this study is to summarize the state of the art of knowledge on the potential and practice of carbon finance for carbon sequestration in global rangelands. While carbon finance projects in the forestry sector have been operating for some years, there are still few rangeland carbon finance projects. Whether carbon finance projects in rangeland areas are feasible or not depends in part on a range of site-specific factors. Some common features of rangelands and communal grazing systems may present challenges to realizing the potential of carbon finance. Rangeland carbon finance potential is also constrained by the regulations driving current carbon market developments. The challenges and potential ways to address them are discussed, highlighting current knowledge gaps, sustainability and equity issues, and constraints on capacities for developing rangeland carbon finance. Some recommendations for action-oriented research and policy development are made.

The focus of this study is on pastoralists in developing country contexts. It does not discuss GHG abatement strategies in intensive production systems, though data from extensive grazing systems in energy-intensive production systems in developed countries is used where data from other pastoral areas is lacking. This study also focuses on carbon sequestration and does not deal with the potential to mitigate emission of other GHGs, such as nitrous oxide and methane. Although these gases make significant contributions to emissions from the global livestock sector (Steinfeld et al 2006) [2] and several methane avoidance projects have already begun operation, [3] the justification for this omission here is that N_2O emissions are mostly associated with fertilizer use in intensive systems, and current methods for mitigation of CH_4 emissions in livestock systems are mostly not suited to

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[2] Methane (CH_4) and nitrous oxide (N_2O) have a 25 and 298 times higher global warming potential respectively compared to CO_2 over a 100 year lifespan (IPCC 2007).

[3] Registered CDM methane avoidance projects and the methodologies used can be found at http://cdm.unfccc.int/Projects/projsearch.html.

application in extensive livestock production systems of developing countries. [4] Furthermore, Smith et al (2008) show that reductions in CO_2 emissions account for 89% of the total mitigation potential of agriculture globally up to 2030.

This report is outlined as follows:
Section 2: A summary of the current status of rangeland ER eligibility and demand for rangeland ERs
Section 3: A summary of existing information on the biophysical, economic and institutional feasibility of carbon finance in rangelands
Section 4: An analysis of capacity constraints for rangeland carbon finance and requirements for carbon finance readiness
Section 5: A discussion of potentials, constraints and recommendations for future actions.

2.Eligibility and demand for rangeland emissions reductions in carbon markets

To avoid dangerous levels of climate change, OECD countries, as well as rapidly industrializing countries such as China and India, must reduce their GHG emission intensity. Compliance markets originate from governmental or intergovernmental regulations determining a cap on emissions of carbon and other greenhouse gases like methane and nitrous oxide. These regulations are the main driver of demand for the rapidly growing carbon market. The carbon market can be classified in three market segments, (i) the Kyoto compliance market, (ii) other compliance or pre-compliance carbon markets and (iii) the voluntary carbon market.

The Clean Development Mechanism (CDM) established under the Kyoto protocol provides a trading platform for ERs from developing countries. In the Agriculture, Forestry and Other Land Use (AFOLU) sector, only ERs from afforestation and reforestation activities are eligible. In the EU Trading System (ETS) ERs from AFOLU activities, including rangeland management, are not tradable even where eligible under the Kyoto protocol because of the misperception that the system cannot deal with the risk of reversibility of ERs from land use activities. There is strong support among some countries to include selected land use activities in a post-2012 agreement, and the European Parliament's Committee is currently reviewing this eligibility ruling.

Other compliance markets exist in Australia and the US at the state level, e.g. the New-South Wales Greenhouse Gas Reduction scheme (NSW GGAS) or the Regional Greenhouse Gas Initiative (RIGGI) in Northeastern and Mid-Atlantic states of the US. The Western Climate Initiative, covering 11 US states and Canadian provinces, is currently under design. Rangeland ERs are eligible in some current state-level compliance markets.

At federal level, Australia, the US and New Zealand are planning to establish emissions trading systems. The largest carbon market is likely to evolve in the US. The Lierberman- Warner Bill proposes that the US Environmental Protection Agency should define eligible activities and carbon accounting rules for a federal emissions trading system. Drafts of the bill consider AFOLU activities, including rangeland activities at the national level, and forestry at both national and international levels. But there is very limited time to complete the bill if a post-

[4] For overviews of other GHGs in the livestock sector and mitigation methods, see Steinfeld et al (2006), Smith et al (2008) and various papers in Rowlinson et al (2008).

Bush administration wants to sign a post-2012 international climate agreement at the UNFCCC conference in Copenhagen in late 2009.

The voluntary market basically trades ERs that cannot be used for regulatory compliance. The market also serves as an incubator for innovative ER activities that are not eligible under any compliance market regime. The voluntary market is tiny compared to compliance markets. In 2007, the voluntary carbon market exchanged 65 million tCO_2e (Hamilton, et al 2008), of which 22 million tCO_2e were transacted by the Chicago Climate Exchange (CCX). Since 2007, in close cooperation with US farmer organizations, the CCX has been trading ERs from rangeland management activities. The vast majority of the buyers of voluntary carbon credits are private businesses.

Table 1: Eligibility of AFOLU ERs by standard

Standard	Reforestation	Avoided Deforestation	Forest Management	Grassland Restoration	Tillage practices
CDM	Yes	No	No	No	No
VCS	Yes	Yes	Yes	Yes	Yes
CCS	Yes	Yes	Yes	Yes	Yes
Oregon standard	Yes	Yes	Yes	Yes	Yes
RGGI	Yes	No	No	No	No
NSW	Yes	No	No	No	No

Source: Kant (2007) and own information

A few governments have explicitly expressed interest in buying carbon credits from international rangeland or AFOLU projects. But most are cautious about the risks[5] and do not support the development of AFOLU pilot projects. As long as rangeland carbon credits cannot be used for compliance markets, demand for rangeland carbon offsets will remain small. Some governments are establishing funds from the revenues of emissions allowance auctions, and using these funds to support the development of new project types with strong sustainable development benefits. An example is the German Climate Protection Fund, [6] which currently only supports forestry AFOLU activities.

Demand from the private sector to purchase carbon credits results from government regulations setting emissions reduction targets for energy intensive sectors and their companies. Again, unless rangeland carbon credits can be used to meet compliance targets, demand will be limited. In general, the regulated private sector has a huge demand for cost effective compliance credits, but is willing to take a limited risk by buying pre-compliance assets

[5] The operational risk that a project does not deliver the planned ERs and the permanence risk that carbon sequestered in terrestrial sinks is later released into the atmosphere.

[6] http://www.bmu.de/english/climate_protection_initiative/general_information/doc/42000.php

at a discounted price. Given the potential niche for rangeland carbon credits under the proposed Lieberman-Warner bill, a small demand for rangeland pre-compliance assets transacted at the Chicago Climate Exchange (CCX) has arisen. Some private sector companies are supporting the development of agricultural carbon credits in developing countries as part of their corporate social responsibility strategy.

Voluntary carbon assets are purchased mainly by the unregulated private sector as part of their carbon neutral strategy. The private sector is either purchasing carbon credits directly from projects or through carbon funds. In general two types of carbon funds may be interested in AFOLU projects. One type is credit-return funds with the mandate to purchase AFOLU credits, like the World Bank BioCarbon Fund.[7] The other type is highly specialised funds that develop and aggregate carbon assets from AFOLU projects with the long term expectation that these assets will fetch a premium price in the future, e.g. Equator Environmental.[8] Private carbon funds are willing to take a higher risk by investing early in the project development cycle in order to maximise the margin between the bulk purchasing costs (currently between US$3-8) and the retail value (currently around €25/tCO_2e). But to maintain liquidity they often have to sign forward purchasing contracts with strict delivery dates and therefore expect projects to minimise project performance, compliance and delivery risks.

Retailers are often interested in 'charismatic' carbon assets, i.e. assets with an appealing story behind the emissions reduction project. Considering that many private households prefer AFOLU project offsets, rangeland carbon projects have a fair chance in this market segment.

Carbon market development is driven by expectations of future regulatory requirements, and future market opportunities depend on developments in international and national regulatory regimes. The Kyoto Protocol includes all forms of terrestrial carbon in national GHG inventories. Methodological difficulties led to the exclusion of most AFOLU activities from CDM eligibility. The 2007 UNFCCC Bali declaration gave the green light to overcoming final methodological issues that might prevent inclusion of Reduced Emissions from Deforestation and Forest Degradation (REDD), forest conservation and Sustainable Forest Management in a post-2012 agreement. In view of this, the European Parliament will shortly review its earlier decision to exclude forestry activities from the ETS. Soil carbon was not mentioned in the Bali Declaration. Terrestrial Carbon Group (2008), however, is advocating for a post-Kyoto deal which includes REDD as well as other sources of terrestrial carbon.
The risk of non-permanence is one reason why carbon buyers often do not buy ERs from AFOLU projects and why AFOLU ERs have not been made eligible in some major trading systems. This problem is addressed in the VCS procedures by assessing this risk and retaining a risk buffer in which up to 30% of the ERs generated are kept in a separate bank account in case the sequestered carbon is released again. Other ways exist to address the non-permanence risk, such as developing long-term incentive structures like easements with land users. The VCS is in principle receptive to rangeland carbon finance projects. But first a methodology and project have to be developed and approved by the standard. Currently only the CCX has a standard to account for ERs from rangeland management activities. The standard is based on a nationwide model developed by the USDA. Based on comprehensive research, default values have been assigned to the carbon sequestration effects of specific management activities in different agro-ecological zones. The Terrestrial Carbon Group is currently exploring national and sub-national programmatic approaches for all terrestrial carbon sinks.

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[7] www.carbonfinance.org
[8] www.equator.net

3. Opportunities for carbon finance in rangelands

3.1 Rangelands, carbon and rangeland management

Rangelands are defined largely by their use for grazing, and include open grasslands and grassland with low woody plant canopy cover. IPCC studies (Smith et al 2007: 501) use land cover data from FAOSTAT which estimated a global pasture area of 3488 Mha for 2002, or 69% of global agricultural land. Including a wider range of vegetation types suggests a global extent of grazing lands of 5250 Mha (White et al 2000: 13). Grasslands have been estimated to include between 10 to 30 per cent of the world's soil carbon (Anderson 1991; Eswaran et al. 1993). Table 2 presents estimates of vegetation productivity and carbon stocks for different global biomes, including tropical and temperate grasslands. [9]

Common grassland C cycle models generally focus on three or four carbon 'pools': C stored in living vegetation (including above ground biomass and live roots below ground), litter, and soil C. In grassland ecosystems, with limited above ground biomass, as much as 98% of C is stored below ground (Hungate et al 1997). So when considering the potential of grassland vegetation types to sequester C, soil C sequestration is the main potential. Because woody plants store C in above ground biomass, shrubs and trees in grasslands can also have a major impact on total C stocks and rates of sequestration. A large proportion of C that enters the soil C pool is also lost to

Table 2: Carbon storage and sequestration rates of different global biomes

	NPP (tC ha/yr)	Area (Mha)	Total carbon pool (GtC)	Total NPP (GtC /yr)	Estimated sink (GtC yr)	Av sink (tCO_2e ha yr)
Crops	3.1	1350	15	4.1	0.02	0.03
Tropical forests	12.5	1750	553	21.9	0.66	1.36
Temperate forests	7.7	1040	292	8.1	0.35	1.25
Boreal forests	1.9	1370	395	2.6	0.47	1.25
Arctic tundra	0.9	560	117	0.5	0.14	0.92
Mediterranean shrublands	5.0	280	88	1.4	0.11	1.39
Tropical savanna & grassland	7.2	2760	326	19.9	0.39	0.51
Temperate grassland	3.8	150	182	5.6	0.21	0.51
Deserts	1.2	2770	169	3.5	0.20	0.26
Ice		1530				
Total		14910	2137	67.6	2.55	

Source: Grace et al 2006

[9] For other estimates of global grassland carbon pools, see Ojima et al 1993, Scurlock & Hall 1998, Batjes 1999.

Table 3: Extent of global grasslands

Grassland type	Area (Mha)	% world land area
Savanna	1790	13.8
Shrubland	1650	12.7
Non-woody grassland	1070	8.3
Tundra	740	5.7
Grassland total	5250	40.5

Source: White et al (2000): 14

the atmosphere due to soil respiration, so net C sequestration depends primarily on:
(1)the rate of input of organic matter;
(2)the rate of decomposition of organic matter; and
(3)the rate of C loss through soil respiration.

These rates are affected by several factors. The level of organic matter inputs into natural rangelands depends on the amount and rate of biomass growth. Rates of decomposition are mainly determined by climatic variables (such as water availability and temperature), microbial activity and soil structure. Soil organic carbon (SOC) stocks tend to be higher in soils with higher soil clay content. Soil respiration rates are also affected by climatic variables. Because of the influence of these factors, ecosystems characterized by different precipitation and temperature regimes and soil types have different potentials for C sequestration. Parton et al (1995), for example, provide general indications that sequestration rates range from 1.83 tCO_2e ha/yr in temperate steppe to 2.57 t CO_2e/ha/yr in tropical dry savannas, and 12.47 tCO_2e/ha/yr in tropical humid savannas.

Creating a carbon asset requires that land managers implement additional management practices that deliver credible increases in C stocks or decreases in C losses or GHG emissions. Management practices impact on existing C stocks, rates of soil C sequestration and GHG emissions. Carbon stocks can be reduced through land degradation or through conversion of grasslands to other uses, such as agricultural cultivation. A range of management practices can also have major impacts on rates of organic matter input and decomposition as well as soil respiration. For example, overgrazing so that vegetation cover declines, or mowing in cut-and-carry systems can reduce the amount of organic matter input into grassland soils. Overgrazing can affect soil temperature because of trampling effects, and thus influence microbial activity and rates of decomposition. Improper management can also decrease vegetation cover and water infiltration rates, thus influencing soil respiration rates. From a rangeland soil carbon management perspective, management practices that increase C inputs to grassland soils or that decrease C losses are considered ‘good’ practices, while actions that decrease C inputs or increase losses are considered ‘bad’ practices. Table 4 presents a range of management practices that are considered in more detail in this study.

Table 4: Management practices with potential to increase C sequestration or decrease C losses in rangelands

Increasing C inputs	Decreasing C losses
1. Increasing biomass C inputs to soil by improved grazing management, e.g. ● Improving (reducing or increasing) stocking rates ● Rotational, planned or adaptive grazing ● Enclosing grassland from livestock grazing. 2. Increasing biomass, by ● Seeding fodder grasses or legumes ● Improving vegetation community structure ● Fertilization.	3. Improved management of land use conversion, e.g. ● Converting agricultural land use to permanent grassland ● Avoiding conversion of grassland to cultivation ● Avoiding conversion of forest to pasture 4. Fire management and control 5. Alternative energy technologies to replace use of shrubs / dung as fuel.

It should also be borne in mind that most C-sequestering practices also have other benefits. Increasing soil C content will generally improve soil fertility, with benefits for the productivity of grassland vegetation. Improvement in the health and productivity of rangeland vegetation is likely also to benefit livestock production, and thus the livelihoods of livestock-dependent pastoralists. Improving soil quality can also improve water retention capacity, reduce soil erosion and preserve biodiversity. The benefits of C-sequestering practices should also be seen from the perspectives of environmental services provided by rangeland managers and resource management that supports sustainable pastoralist livelihoods.

There are, however, risks of negative impacts associated with some C-sequestering management practices. For example, fertilization often increases soil C stocks, but may also increase emissions of N_20, affect soil structure, pollute water supplies and increase net emissions due to fertilizer production related fossil fuel emissions. Introduced exotic grass and legume species may behave as invasive species and threaten native biodiversity.

After long periods of net C sequestration, soil C stocks become saturated. The implication for carbon finance potential is that further management actions may not actually increase the amount of C sequestered, and thus the potential for carbon finance would be limited. There is still great uncertainty over the length of time required for grassland soil C stocks to reach saturation levels. Jones and Donnelly (2004) cite studies estimating between 10 and 100 years. Conant et al (2001) cites studies reporting linear increases in soil C stocks after as long as 40-60 years. Many estimates of the C sequestration potential of rangeland soils opt for more conservative time periods, typically between 10 and 25 years.

Table 5: C sequestration potential of improved grassland management in different climate zones

Climate Zone	(tCO_2/ha/yr)		
	Mean estimate	Low	High
Cool-dry	0.11	-0.55	0.77
Cool-moist	0.81	0.11	1.50
Warm-dry	0.11	-0.55	0.77
Warm-moist	0.81	0.11	1.50

Practices surveyed include grazing management, fertilization and fire management. Source: Smith et al (2007: Table 8-4)

3.2 C sequestration potential of specific management practices

What rates of C sequestration can result from different management practices in different rangeland ecosystems? Table 5 presents the results of an IPCC literature review. For the purposes of this paper, based on the systematic review by Conant et al (2001), we developed a database on the C sequestration potential of management practices in rangelands (Table 6). The database draws from long-term studies of the C sequestration effects of management practices. The following analysis draws on this database and other published data.[10]

Table 6: C sequestration potential of rangeland management practices

Management practice	No. of data points*	Mean change in tCO2e/ha/yr or total change in %C	Min – max
Vegetation cultivation	c: 31 %: 7	9.39 tCO_2e/ha 0.56%	-12.1 - 46.50 $tCO_2e/ha/yr$ 0.11 – 1.14%
Avoided land cover/ land use change	c: 65 %: 22	0.40 tCO_2e/ha 0.87%	-103.78 - 15.03 $tCO_2e/ha/yr$ -0.7 - 4.2%
Grazing management	c: 55 %: 21	2.16 t CO_2e/ha 0.13%	-12.47 - 33.44 $tCO_2e/ha/yr$ -2.03 – 5.42%
Fertilization	c: 27 %: 68	1.76 t CO_2e/ha 0.47%	-11.73 - 9.09 $tCO_2e/ha/yr$ -1.23 - 4.8%
Fire control	c: 2 %: 1	2.68 t CO_2e/ha 0%	3.67 – 4.11 $tCO_2e/ha/yr$ 0%

*c = no. of studies reporting in C content, % = no. of studies reporting in %C

Tables 5 and 6 show that almost all management practices may have either positive or negative impacts on grassland soil carbon stocks. Some people in the carbon finance sector may misconstrue this as indicating inconsistent results from scientific research ('lack of scientific consensus'), and thus dampen their interest in the potential of rangeland carbon finance. Investigation of the literature shows that whether a specific practice has positive or negative C sequestration effects depends on a range of site-specific variables, such as vegetation and soil types, climate and land use history. That some types of rangeland may respond positively to a certain practice, while the same practice may reduce C sequestration rates elsewhere, has been well established through thorough research. This implies, therefore, that a practice which is suited in one place may not be suited elsewhere (Smith et al 2007: 513). All practices considered here have been shown to have positive C sequestration effects in a number of contexts. Examples of large negative sequestration effects of implementing a 'good rangeland management practice' are almost all extreme outliers from the literature.

The following subsections summarize potential C sequestration rates and issues for these management practices in different rangeland contexts.

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[10] Carbon fluxes are strongly influenced by climate factors as well as management practices, so direct measurements show highly variable results. This database has only drawn on long-term studies. The database is described in Appendix 1.

Grazing management Global studies find that grazing can either have a positive or negative impact on rangeland vegetation and soils, depending on climatic characteristics of rangeland ecosystems and grazing history (Milchunas & Lauenroth 1989) and effectiveness of management (Briske et al 2008). Common grazing management practices that might increase C sequestration include stocking rate management, rotational, planned or adaptive grazing, and enclosure of grassland from livestock grazing.

Table 6 shows that for 55 data points reporting changes in absolute levels of soil C in response to grazing management interventions, the average annual increase in C stocks was 2.16 tCO_2e/ha. There was, however, great variation, with 24 out of 76 grazing management data points reporting decreases in soil C stocks or concentration in response to 'moderate' levels of grazing intensity.

(i) Stocking rate management: Conventional rangeland science suggests that sustainable management of grassland can be achieved by grazing livestock at stocking rates that do not exceed the carrying capacity of grasslands.

In some contexts, vegetation productivity and soil C stocks both change linearly in response to reductions in grazing intensity, as shown by research on yak grazing intensity in alpine meadow on the Tibetan Plateau (Dong et al 2005). This implies that reductions in stocking rates would enhance alpine grassland soil C sequestration.

In other – often more arid – contexts, soil C stocks are unchanged or even increased by long-term heavy grazing (Biondini et al 1998; Schuman et al 1999; Reeder et al 2004). In these contexts, climatic variables have a much greater effect than grazing impacts, and grazing-adapted grasses respond to heavy grazing by increasing allocation of C to below ground carbon pools. Again, this would imply that appropriate stocking densities can improve soil C sequestration. Similar results have been reported from Sudanese savannas (Ardö and Olson 2003).

(ii) Rotational, planned or adaptive grazing: Many grasslands increase biomass production in response to frequent grazing (Klein et al 2007; Hiernaux & Turner 1996), which when managed appropriately could increase the input of organic matter to grassland soils. A review of global studies (Briske et al 2008) found that rotational grazing often does not increase biomass production. There have been very few studies of the effects of rotational grazing on soil carbon stocks. Two published reports both indicate that rotational grazing would have limited impacts on soil carbon stocks, despite the benefits for livestock production and/or vegetation (Badini et al 2005; Xu et al 2001). Site-specific planned and adaptive grazing is likely to be more effective in managing soil carbon but no published reports have been identified.

(iii) Enclosure from livestock grazing: The US Conservation Reserve Programs and the Chinese 'Return Grazed Land to Grass' Program are large scale programmes that support enclosure of degraded grasslands from livestock grazing for defined periods of time. Studies from Inner Mongolia, China, also report positive sequestration rates (2.35 – 4.33 tCO_2e/ha/yr) after excluding livestock from degraded grasslands (Li et al 2007; Zhou et al 2007). Excluding grazing can aid in recovery of degraded grasslands in semi-deserts (Pei et al 2008), as well as warm-moist ecosystems (Amezquita et al 2008).

Because grazing may be beneficial for vegetation production and C allocation to soils, it has also been found that exclosure of livestock does not benefit grassland soil C sequestration in some semi-arid rangeland (Nosetto et al 2006; Shresta & Stahl 2008) and savanna contexts (Moussa et al 2007). Enclosure of grasslands from livestock grazing may also restrict the access of livestock keepers to functional grazing lands, adversely affect herders' incomes and displace grazing intensity onto unenclosed lands (Williams 1996).

Box 1: CCX Rangeland Offset Credits
The National Carbon Offset Coalition (NCOC) is an aggregator registered with the CCX. It works with land owners to develop rangeland carbon sequestration projects and pools them for trading on the CCX. Land owners must provide maps of the enrolled location and records of past and current stocking rates. Eligible activities include stocking rate management, rotational grazing and seasonal use on non-degraded and degraded grasslands. The amount of C sequestered is calculated using default values for C sequestration of different practices depending on ecological zone and land health. Land owners are paid annually with 20% held in reserve in case the project fails.
Source: NCOC (2007)

Vegetation cultivation for increased biomass: Cultivation of grasses and legumes, and management of vegetation community structure may increase rangeland soil C sequestration. Table 6 shows that for 38 reports on vegetation cultivation, annual soil C sequestration rates varied between -12.1 and +46.5 tCO_2e/ha with an average of +9.39 tCO_2e/ha. This variation is due to differences in location (e.g. ecosystem properties, soils etc) and specific measures (e.g. species planted). The highest sequestration rates were from tropical pasture systems in Latin America (averaging 16.1 tCO_2e/ha/yr), where silvopastoral systems integrating improved pastures with management of trees and shrubs are already showing potential for attracting support from carbon finance (Box 3). A systematic study of C sequestration in Latin American silvopastoral systems is given by t'Mannetje et al (2008). A major caveat to note is that if cultivation of perennial pastures involves plowing of soils, large C losses are expected to occur (Davidson & Ackerman 1993).

In many semi-arid rangelands, shrubs are an important component of rangeland vegetation. Patches of shrub vegetation in semi-arid rangelands and savannas have been found to overlie what have been termed 'fertile islands' of higher water infiltration and C sequestration (Tongway & Ludwig 1990; Ludwig et al 2000). Studies on mesquite encroachment in the USA find that mesquite stands can contain as much as twice the SOC as open grasslands (McLain et al 2008; Martens et al 2005).

Similar findings have also been reported from other countries. Shrub invasion over long period (>100 years) in Australia has been shown to increase soil C stocks by 32 tCO_2e/ha compared to open grassland (Krull et al 2005). In Eastern Cape province, South Africa, subtropical thickets (dominated by Portulacaria afra) can store 245 tC /ha, 68% of which is in the soil, but with above ground biomass contributing more than 20% (Mills et al 2005). Thicket restoration can sequester up to 15.4 tCO_2e/ha/yr (Mills and Cowling 2006). Shrub encroachment is often seen as a problem by livestock keepers because establishment of shrub communities fragments rangelands when tree canopies exclude cattle grazing.

Box 2: Subtropical Thicket Rehabilitation Project (STEP) In Eastern Cape, S Africa, subtropical thickets (dominated by Portulacaria afra) have degraded due to browsing. Nutrient cycles, water infiltration, and water-use efficiency have suffered, causing desertification. Multi-stakeholder regional planning will be required. STEP is exploring the potential of CF, biodiversity offsets and other Payments for Environmental Services to fund regional rehabilitation activities.
Source: Powell et al n.d.

Fertilization: Application of fertilizer aims to increase nutrient availability with which to stimulate vegetation productivity. This can increase C inputs into rangeland soils. Table 6 reports an average annual CO_2 sequestration rate from fertilization of 1.77 tCO_2e/ha/yr, and an average change in C concentration of 0.47%.

Fertilization is unlikely to be viable as a management practice in many rangeland carbon finance project contexts: (i) Fertilizer implies expensive (possibly recurring) costs which would have to be either financed by the land owner or deducted from the carbon revenues. (ii) The production of inorganic fertilizers emits significant amounts of CO_2 into the atmosphere, so the net C sequestration of fertilizer application may be negative. Lee and Dodson (1996) provide the figure of 5.1 kg CO_2 emitted per kg of nitrogen manufactured. (iii) Nitrogen fertilizer applied to grasslands may increase emissions of N_2O, another GHG. Emissions from fertilizer use have to be deducted from the ERs claimed.

Avoided land use change: Land use change has large impacts because of the degree of change in C stocks per hectare and the scale of the changes induced. Avoided land use and land cover changes have potential to prevent major changes in regional C budgets. A global analysis by Guo and Gifford (2002) found that soil C stocks decline after land use changes from grassland to plantation (-10%) and grassland to crop (-59%), but increase after changes from native forest to pasture (+8%) and arable cultivation to pasture (+19%).

(i) Grassland – agriculture conversions: In the database created for this study, 38 data points show that conversion of arable land to permanent pasture almost always has positive net C gains (average total gain of 0.48 tCO2e/ha and average gain of 1.32% C concentration).

A literature review of grassland conversions to cultivated land concluded that cultivation of previously untilled soils typically results in a loss of soil C stocks of 20-40%, most of which is lost in the first few years after tillage (Davidson and Ackerman 1993). Guo and Gifford (2002) found that cultivation of grasslands leads to an average soil C loss of 59%. Avoided land use conversions can sequester carbon if conversion of grassland to cultivated land forms part of the baseline scenario.

Box 3: Caribbean Savannah Carbon Sink Project (CBCSP)

Degradation of pastures in Colombia's Caribbean savanna is a major cause of poverty among the disadvantaged indigenous inhabitants. With support from national and international research agencies, the regional government is leading reforestation and establishing silvopastoral schemes on 2200 ha of degraded land. Initial investments are high and small holders' returns only flow after 5-6 years, but can generate significant CF flows later on, which will be invested in implementing the Zenu Indigenous People Plan.

Source: World Bank (2007)

(ii) Grassland – forest conversions: The data base summarized in Table 6 contains 49 data points on the conversion of forest to grassland. Six data points measured the change in terms of soil C concentration (average -0.9%). 43 data points measuring soil C change in absolute terms averaged 6.5tC/ha, or an average annual sequestration rate of 1.28 tCO_2e/ha.yr. 17 of the 49 data points recorded negative C sequestration from forest conversion, while in 32 cases positive C sequestration rates were recorded. These figures refer only to changes in soil C stocks, not total ecosystem C. Fearnside and Barbosa (1998) found that conversions from Brazilian tropical forest to pasture caused a total C loss of about 34.8 tCO_2e/ha. Soil C only increased in well managed pastures. t'Mannetje et al (2008)' study of C sequestration potential of silvopastoral systems argues strongly for incentive systems that reduce deforestation.

Because forests contain significant above ground as well as below ground C, there is significant potential for C sequestration through grassland-forest conversions. When compared to well managed improved grasslands in Latin America, native forests contain 40% more C (t'Mannetje et al 2008: 16). That study finds that even dispersed trees make significant contributions to total ecosystem C in the silvopastoral systems studied. Even accounting for a 10% decrease in milk and meat production due to the shade effect of trees, modeling of the economic benefits of retaining dispersed trees in improved pasture showed that the net benefits are positive both with and without a carbon finance payment (ibid.: 138). Silvopastoral systems have begun to realize their potential in carbon markets (Box 3).

Trees are also crucial components of many other semi-arid and savanna rangelands (e.g. Krull 2005; Abule et al. 2005; Woomer et al 2004). Afforestation – which normally also necessitates exclusion of livestock grazing – has been shown to sequester significantly more C than grazed grasslands (e.g. Nosetto et al 2006). Only reforestation and afforestation projects are eligible for support under current CDM rules. There has been growing interest in grassland afforestation projects. A number of applications for new methodologies integrating afforestation and livestock keeping have been made to UNFCCC. [11]

At present, grassland afforestation has the most immediate potential for creating carbon assets. In some contexts afforestation and pastoral use can go together (Box 4). In other contexts, afforestation and removal of grazing livestock present potential challenges to pastoralists, and may serve to restrict their access to traditional grazing lands, or divest them of land rights altogether (see Box 7 below).

Box 4: Afforestation and grazing

The Moldova Soil Conservation Project aims to conserve soils on 14,494 ha of degraded pasturelands through afforestation. Social assessment confirmed that only degraded and overgrazed land areas with very limited forage value are targeted. Because afforestation plots are dispersed and small, pasture access is not disrupted. Afforestation plots account for only a small proportion of grazing lands in each village, and sufficient communal grazing lands remain to avoid increased livestock density in non-afforested grasslands and to prevent adverse effects on shepherds' livelihoods.

Source: World Bank (2003)

Fire management: Fire is an integral feature of many rangeland ecosystems. Fire is often used to favour the growth of grasses over woody species to improve forage supply. Suppression of woody species limits C sequestration in above ground biomass and soils. Burning also releases CO_2 and other GHGs (mostly CH4, but also N_2O and other GHGs). Savanna burning has been estimated to emit 1.8-15.4 Gt CO_2e per year (Grace et al 2006).

Fire management entails reducing the frequency or extent of fires, reducing the fuel load through litter management, and management of the timing of burns (Korontzi et al 2003). Fire management can sequester 0.9-9.2 tCO2e/ha/yr (Scholes & v.d. Merwe 1996, Bird et al 2000). Experience in Australia suggests a real potential for creating carbon assets through fire management (Box 5).

[11] http://cdm.unfccc.int/methodologies/PAmethodologies/publicview.html

Box 5: The West Arnhem Fire Abatement Agreement (WALFA)

WALFA is a partnership between Darwin Liquefied Natural Gas (DLNG), the Northern Territory Government, the Northern Land Council, Aboriginal Traditional Owners and indigenous representative organizations, formed to implement strategic fire management across 28,000 km^2 of Western Arnhem Land. CO_2 emissions will be offset by post-fire regrowth, so the agreement covers CH4 and N_2O emissions. Increasing the proportion of early dry season fires creates fire breaks and patches of burnt country which reduce the extent of late dry season burning, thus abating ca. 100,000 t CO_2e/yr. The agreement is a fee-for-service agreement with indigenous fire managers but GHG accounting practices are consistent with CF practices, so when the market evolves, there is potential to link with carbon trade. Implementation has strengthened indigenous land management organizations and transmission of indigenous knowledge, and generated income for the disadvantaged Aboriginal communities.

Source: http://savanna.ntu.edu.au/information/arnhem_fire_project.html

Alternative energy to reduce carbon losses / emissions: Shrubs and trees can be important contributors to rangeland C stocks. Use of woody biomass for heating and cooking (often both by herders and by urban residents) can contribute to vegetation degradation and loss of C stocks as well as CO_2 emissions from combustion. Use of livestock dung for fuel can also reduce C inputs into grassland soils.

Establishing agro-forestry systems can help meet fuel wood needs as well as improving soil structure (Kürsten 2000). Alternative energy (biogas, solar and wind power) can help control desertification, increase C sequestration and reduce CO_2 emissions, as well as reducing pastoral women's exposure to indoor smoke. Alternative energy technology adoption has already begun with support from carbon finance sources (Box 6).

Box 6: Solar cookers as an alternative energy technology in rangeland areas

A solar cooker, if used for 40% of the year, can reduce up to 3.5tCO_2e per year. Implementation of 10,000 units may result in carbon revenue of $ 140,000 - 350,000 (GM 2008). Solar cooker offset projects have potential in rangeland areas. Examples of retail offset projects include Solar Cooking Units in the Andes (Action Carbone) and the East Africa Solar Ovens project (CO_2 Balance).

3.3 Measuring and monitoring C changes

For a carbon finance rangeland project, a methodology has to be developed providing the measurement protocol for determining the C baseline and for monitoring C changes after adoption of sequestration practices. The methodology would incorporate as guiding document the IPCC good practice guidelines for land use, land use change and forestry (IPCC 2004) and guidelines for national GHG inventories (IPCC 2006). Certain modules can be also adopted from the 10 approved CDM forestry methodologies and the supporting tools,[12] the Voluntary Carbon Standard or the slightly outdated CCX protocol.

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[12] http://cdm.unfccc.int/methodologies/ ARmethodologies/approved_ar.html

The IPCC recognises three methodological levels. Tier 1 methods use IPCC default values for the respective ecosystem. Tier 2 methods use country-specific data and coefficients. Tier 3 methods use locally collected data. Tiers 1 and 2 rely heavily on modelling approaches, often using the CENTURY model.

Baseline measurement and monitoring can use either direct or indirect approaches. Direct soil carbon monitoring is expensive, and because of soil heterogeneity is only accurate at high sampling densities. Moreover, because of scale requirements of CF projects, the minimum project area is likely to be over 100,000 ha. Poussart et al (2004) show that very large samples (several hundred) are required to demonstrate changes in C stocks over time in a semi-arid ecosystem in Sudan. Smith (2005) cites costs of US$3-20 per sample depending on labour costs. Monitoring methodologies must therefore consider the trade-off between certainty and cost. Because the majority of rangeland C is belowground, and considering the costs involved, above ground grass carbon measurement is not practical. The combination of general soil information, remote sensing and plot specific data to understand correlations between variables and enable soil carbon modelling (see e.g. t'Mannetje et al 2008) is generally the most appropriate direct approach.

An indirect approach would rely on default values based on earlier research applications of the direct approach together with statistical information on soil, climate, land use practices, and monitoring not of changes in C stocks but of adoption of improved land use practices by land users. The advantages of the indirect approach are that the methodology is expected to be more cost efficient, relies on local capacity and has a high transparency for the herders in the sense that they know what they get if they adopt a specific land management activity. A methodology based on the indirect approach has yet to be approved.

3.4 Economic feasibility of rangeland management options

Adoption of C-sequestering rangeland management practices will only happen if adoption provides additional net economic benefits to land users compared to current practices. As the price paid per tCO_2e sequestered increases, one would expect the rate of adoption of C sequestration practices to increase (Smith et al 2008).

Rangeland users can be expected to adopt C-sequestering practices when the net benefit (i.e. benefit-less-cost) of these practices is higher than the net benefit of current management practices.[13] There is scant documentation of current costs (UNFCCC 2007) and benefits faced by pastoralist producers across the world, and in many cases pastoralists' household economies are not well understood at all. In the absence of more detailed economic studies, Table 7 gives an illustrative indication of the cost : sequestration ratio of various management practices based on current implementation prices in China (expressed in US$). Column 4 can be understood as the minimum ER price at which each practice becomes economically feasible.

Table 7: Cost per tCO_2e sequestered for various rangeland management practices

Practice	Cost ($) / ha	tCO_2 e seq ha/y	Cost ($)/ tCO_2 e for 10 yr
Grass / legume planting	116	10.97	1.06
Shrub cultivation	199	9.75	2.04
Grassland enclosure	570	3.89	14.65
Afforestation of grassland	225	15.40	1.46
Alternative energy	60 per hh	3.5 / hh/yr	1.71

Notes to Table 7: Sequestration potential is the mean for each practice from the database or other cited literature. Costs do not include opportunity costs and are based on current implementation costs in China, including material and labour costs (authors' own data). Cost/tCO2e is estimated over 10 years of implementation

Table 8 summarizes the findings of available studies of the economic feasibility of C sequestration in rangeland settings. The main lessons highlighted are: (i) high initial costs may require subsidization; (ii) households with different capital and resource endowments will have different access to adoption of management practices and different potential to realise economic benefits; and (iii) C payment incentives vary with the price of tCO_2e.

[13] Tschakert (2004) shows that seasonality of household budgets is also an important constraint.

Table 8: Findings of studies of economic feasibility of adopting C sequestration practices in a variety of rangeland settings

Management practices (source)	Context	Findings
Improved pasture with retained/ re-established dispersed trees ('t Mannetje et al 2008)	Latin America (Colombia: Andean hillsides & Amazonia; Costa Rica: tropical)	Investments with and without C payments profitable for all farm types compared to current management; small-medium farms need assistance with capital investment & technical assistance, large farms need technical assistance only. Transaction costs for small farms may preclude their involvement.
Conversion of wheat & maize fields to thicket stands and rehabilitating thicket as alternative to goat farming (Mills et al 2003)	South Africa	Farmers' incentives to adopt depend on (i) number of years required for thicket restoration (C sequestration) and (ii) current & future price of C/t. Price of C/t depends on outcomes of international negotiations in coming years.
Fire control (Ockwell & Lovett 2005)	Cape York Peninsula, Australia	When there are no C payments, fire assisted pastoralism has the highest NPV while the NPV for forestry is negative; when there are C payments for fire control both uses give positive NPVs, but forestry NPV is 3 times higher than for fire assisted pastoralism
Cropland conversion to grassland; hedgerow planting; animal fattening; manure use (Tschakert 2004)	'Old Peanut Basin' Senegal (agropastoral)	High initial investment costs preclude most households from adoption unless subsidized; benefits of C payment less than incomes from most activities;poor households only have net gain from engaging in one activity type, but middle-rich households can gain from several. Seasonality of household budget flows have big impact on affordability of initial investments.
Grazing exclusion (de Steiguer 2008)	Arizona State-owned semi-arid rangelands	Of 12 sites modelled, costs of C sequestration pertCO_2e are lower than the price offered by a range of offset traders

3.5 Institutional feasibility

Aggregation and project institutions Rangelands are often in large contiguous areas, and per household areas are often much larger than in agricultural zones. This presents good potential for generating carbon assets that exceed the minimum scale required for CF projects, and that generate sufficient income streams to provide benefits at the household level.

CF projects generally have an organization ('aggregator') to aggregate individual households' carbon assets within the project area. Aggregators provide the link between land users (producers of carbon assets) and purchasers of those assets. The role of an aggregator includes signing contracts with land users, monitoring contract compliance and managing the funds generated from sale of carbon assets. CCX Rangeland Management Soil Carbon Offsets in the USA are aggregated by state Farmers' Unions and Farmers' Associations. In other contexts, NGOs with a credible track record or communal pastoralists' representative organizations could play this role.

Implementation of C sequestering practices will often also require an extension service provider to provide land users with access to the materials, information and training required to implement improved management practices. Extension agencies, which may be research organizations, government technical extension agencies or NGOs with a relevant track record, will be contracted by the implementing organization to provide the required services. The costs of extension services will either be covered by fee-for-service charges to land users recovered from project revenues or paid for by third party project funding. The arrangements adopted would depend on the results of financial analysis in the project feasibility study stage.

Project boundaries and tenure issues Projects must have a clear project boundary and clear tenure rights over the rangeland in order to ensure that land users implement the agreed management practices that lead to C sequestration. The appropriateness of different rangeland tenure policies has long been contentious in many parts of the world. Where land use rights have been privatized (e.g. most of Latin America and China, parts of east Africa) and where land right holders are able to exclude other users, this may facilitate eligibility for CF. This applies also to areas where land use rights are communal but legally recognized (e.g. parts of China, some countries in West Africa) as well as where rights are held at the household level.

Where pastoralists' traditional land use does not have legal recognition, or where pastoralists are unable to exclude others from land use, this presents significant challenges for implementing CF projects (Roncoli et al 2007). Where pastoralists lack formal land use rights, or where legal land rights exist but are not yet enforced, demonstrated potential for producing CF flows may potentially aid in pastoralists' lobbying for their land use rights. This may prove to be the most significant benefit of carbon finance projects in some pastoral areas. As with biofuel and other projects that increase the value of land, there is also the risk that CF projects would promote privatization of rangelands in areas where communal access and traditional management has many important ecological and social functions (Box 7).

Box 7: Carbon finance and the land grab

A study by Rights and Resources Initiative (RRI) shows that growing demand for land for food, biofuels and wood products will require an additional 515 million ha of land by 2030. Without explicit recognition of communities' rights over land, government allocations of land for industrial plantations will divest communities of access to lands. Because jatropha can be grown on marginal farming lands which may be vital grazing lands, a report by IIED on the impacts of biofuels identifies pastoralists as particularly vulnerable to losing access to grazing lands.

Sources: RRI (2008), Cotula et al (2008)

National level institutions The designated national authority (DNA) is responsible for approving carbon finance projects under the UN climate change convention. Without engagement of the DNA, carbon asset purchasers cannot be sure that rights over the assets will not be revoked by subsequent national initiatives. Before a project is approved it is assessed against the national sustainable development criteria, considering social, environmental and economic benefits and potential negative impacts.

In most countries the DNA is also the first contact point for carbon funds and project developers, and the lead agency in providing capacity building in carbon market engagement. However, in practice DNAs with limited resources are mainly involved in the international climate change negotiations and disseminating decisions from those negotiations. For sectoral expertise, the DNA relies on the relevant line agencies and therefore often has only limited interaction with civil society.

DNAs are responsible for overseeing the development of national and sectoral GHG inventories which provide robust and transparent documentation of the baseline emission scenario. A common approach to developing carbon finance projects for a given sector is to first complete a GHG inventory, as this enables one to identify the major sources of emissions, from which one can then identify mitigating actions and calculate the costs of emissions abatement for the sector. Pilot projects can then be initiated within the overall national framework established.

The architecture of a post-2012 climate change agreement may well be based on national terrestrial carbon budgets or sectoral budgets and sub-national mitigation activities.[14] This system requires substantial investments in developing national GHG accounting systems. Early mitigation action may start before the national system is in place. Such a system will be based on national sovereignty rights, but also consider ongoing decentralisation processes in rural areas.

To date, Africa in particular has hosted very few CDM or voluntary carbon projects. A number of initiatives are underway, such as UNFCCC's Nairobi Framework and the World Bank Africa Assist programme. [15]They focus on DNA capacity building, but also increasingly on learning by doing support to project developers in order to remove project development barriers and to increase market confidence.[16]

3.6 Impacts of climate change

Climate change impacts on grassland C cycles Global climate change is already affecting grasslands and pastoralists across the world. Predicted changes in global climate include increasing concentration of atmospheric CO2, rising temperatures and changes in rainfall patterns and changes in the frequency of extreme weather events. All these changes impact on grasslands, livestock and pastoralists (Nori & Davies 2007; Kirkbride & Grahn 2008; Birch & Grahn 2007).

The effects of climate change on grassland carbon cycles can be expected to differ between different grassland areas. Increasing atmospheric CO_2 concentration has been shown to increase plant productivity (Hall et al 1995).

[14] See Terrestrial Carbon Group (2008)

[15] www.cfassist.org

[16] http://cdm.unfccc.int/Nairobi_Framework/index.html

Increasing rainfall in arid areas will also benefit vegetation productivity. Shorter growing seasons or declining rainfall will lower plant productivity. Where the net effect of these changes is to depress plant productivity, inputs to grassland C stocks decrease. Increased temperatures may also increase soil respiration rates. [17]

Mitigation and adaptation linkages There are significant areas of overlap between improved rangeland C management practices and measures that might assist pastoralists in adapting to climate change. C sequestering rangeland management practices are beneficial for maintaining or improving rangeland productivity. Beyond this, activities that support pastoralists to adapt to specific aspects of climate change (e.g. droughts, severe snowfall) or which assist them in diversifying incomes (e.g. agro-forestry) may also sequester C and be eligible for CF support.

Several least developed countries with significant rangeland areas have produced National Adaptation Programmes of Action (NAPAs)[18] which outline potential or planned responses to climate change, such as support for community-based rangeland management, restoration of degraded rangelands, afforestation, grass and legume cultivation. Many of these activities are likely to sequester carbon as well as supporting adaptation.

GEF Adaptation Funds[19] have supported several rangeland management projects which sequester carbon, although the ER credits have not been claimed.

17 See for example Hall et al (1995), Parton et al (1995), Shaw et al (2002).

18 http://unfccc.int/national_reports/napa/items/2719.php

19 www.undp.org/gef/adaptation/funds/04_1.htm

4. Rangeland CF readiness

There are few rangeland carbon finance projects to date. Early pilot projects can provide valuable experience to aid in advocacy for inclusion of rangelands and soil carbon in future intergovernmental climate change agreements. In the course of this study, feedback was received from rangeland project managers regarding their readiness for implementing rangeland carbon finance projects.

Many organizations working with pastoral peoples have rich practical experience and strong capacities in supporting the extension and adoption of mitigation activities that benefit grassland health, livestock productivity and herders' livelihoods. Even where these organizations are aware of the growing potential of global carbon markets, there are constraints on accessing and attracting carbon finance. At the international and national levels, there is limited awareness of the potential contribution of pastoralists to emissions mitigation. Pastoralists are rarely thought of as a provider of substantial amounts of carbon offsets. Potential project developers also may not understand well the rangeland-specific opportunities provided by these markets, and may not know how to make contacts with carbon market actors. Capacity building and advocacy is crucial to remove these barriers.

Another key barrier expressed was the initial investment required to develop pilot projects and accounting methodologies for rangeland projects that are simple, cost efficient and widely applicable. There is a misperception that expensive soil carbon measurements are required along the lines of the region-wide research that preceded development of the CCX rangeland programmes (see Box 1 above). Targeted public investment in pilot projects and accounting methodologies will substantially reduce project development costs for subsequent projects that can adopt the experiences and the methodologies developed.

Table 9: SWOT analysis of carbon finance potential in rangelands

Strengths: Large area, good aggregation potential Co-benefits: •Ecosystem benefits •Livestock production benefits •Pastoralist welfare benefits •Potential to promote legal recognition for traditional land use rights	**Opportunities:** Funding potentially available for pilot projects, incl. methodology development High sequestration potential of some practices in some ecosystems Landscape based project approaches Potential links with climate change adaptation funding, conservation banking and other PES schemes
Weaknesses: Lack of scientific research in many areas, and investment required to develop baselines Permanence / reversibility risks No legally recognized rangeland tenure in many pastoralist areas	**Threats:** Leakage if sub-national approaches are used Climate change likely to reduce C sequestration potential in some areas Emerging post-2012 framework may continue to exclude soil carbon from compliance markets

5.Potentials, constraints and ways forward

5.1 Potentials

This report has identified the following potentials for rangeland CF:

- Rangelands cover a large portion of the world's surface, and are often degraded to some extent, suggesting a large total C sequestration potential
- Rangelands are often in large contiguous areas, so there is potential for land users to benefit
- Several management practices have been shown to increase C sequestration in a variety of rangeland contexts across the world
- For some rangeland ecosystems and some management practices, there is already a strong scientific basis at both site and regional levels.

Rangeland projects that meet the following criteria (among others) will be more likely to be developed into CF projects:

- Clear legal rights over rangelands
- Solid scientific documentation of C sequestration impacts of management practices
- Where adoption of these practices is in line with national sustainable development priorities and adaptation plans
- Where institutions involved have capacity to develop projects in accordance with common CF standards, and to support implementation.

Where these criteria are not met, they point to key areas required for capacity building in readiness for future CF market opportunities:

- supporting recognition of pastoralists' land rights
- improving the scientific knowledge base
- supporting incorporation of pastoralists' management practices in national plans
- capacity building for engagement in carbon markets.

In the short-term it is more likely that charismatic rangeland carbon assets would be of interest to the voluntary market. Early pilot action projects and the development of necessary methodologies will also generate important experiences for the compliance market and programmatic or sectoral approaches. Boxes 8-10 give illustrative examples of project types with potential, highlighting how they meet general CF criteria and also the constraints faced.

Box 8: Silvopastoral systems in Latin America

Land degradation is a major cause of poverty in many parts of Latin America. Results of a five year on-farm research project in Colombia and Costa Rica show that compared to degraded pastures, cultivation of perennial grasses and other good management practices can significantly increase soil C stocks within short periods of time. Average annual sequestration rates across all sites and practices were over 4 tC/ha/year. Inclusion of dispersed trees in pastures further increases total C stocks without significantly affecting livestock productivity. The study identified site characteristics (e.g. soil type, slope) associated with positive C gains. GIS was used to estimate the total area in which these measures should be targeted.

Source: t'Mannetje et al (2008)

Box 9: Grazing systems on the Tibetan Plateau

Alpine meadow covers more than 58 Mha on the Tibetan Plateau, and contains between 25-53 tC/ha, more than 90% of which is in soils. 18-year grazing studies show that continuous heavy grazing leads to a halving of soil C stocks. Official figures suggest these grasslands are overstocked by 30-40%. Carbon finance could play a role in providing herders with an incentive to reduce stocking rates. A policy of contracting grassland to households has been implemented in most areas. The average household has clear user rights to more than 110 ha of grassland. Average incomes are below US$1 per day. If reductions in stocking rates could increase soil C sequestration by just 0.5 tC/ha/year, then even at a price half of current carbon prices a herder household might be able to receive payments of over $3700 per year, more than their current annual income, while also preventing the loss of important ecosystem services in this critical region.

Source: Wilkes (2008)

Box 10: Stakeholder collaboration for prescribed fire management

Appropriate management of fire need not be detrimental to soil C stocks. The use of fire is an integral part of traditional rangeland management in many locations across the world, but has often been banned. Multi-stakeholder action research in the Borana highlands of Ethiopia has shown that with careful facilitation, traditional and scientific knowledge can be combined to implement an effective prescribed fire regime. A partnership was formed that included community representatives, a pastoral development agency, an agricultural research institute and technical assistance from the US Forestry Service. With successful response of savanna grasslands to burning, the partnership has since expanded to include other interested parties. Even in communally managed grasslands institutional arrangements can be developed to implement beneficial management practices.

Source: Gebru et al 2007

5.2 Constraints

At present, the biggest constraint on the development of rangeland carbon finance is the exclusion of rangeland ERs from eligibility in compliance markets so demand remains weak. It remains to be seen whether a post-2012 international framework will create demand for a wider range of terrestrial carbon assets, including rangeland carbon. In the interim, it is appropriate to consider carbon finance as one of several alternative financing options for environmental service provision by pastoralists (Box 11). There are also several major knowledge gaps which constrain demand from policy advisors for more serious consideration of the potential of rangeland carbon assets. These include

- Data to support realistic estimates of the global biophysical mitigation potential of rangeland management activities and the related project development and maintenance costs
- Understanding of interactions between climate change, carbon fluxes and management practices, and how this may impact on the permanence of C sequestration.
- Assessment of the social, institutional and legal contexts of rangeland management, and the feasibility of multi-stakeholder collaboration within the framework of carbon finance markets.

Among potential project developers, the main current barriers to developing rangeland carbon finance projects are limited understanding of market opportunities and limited contacts with carbon market actors. Among those interested in developing pilot projects and methodologies, the initial investment costs required to develop these pioneering projects are a constraint.

Box 11 Diversified funding options
Well-managed rangelands provide a variety of ecosystem services. Carbon markets only reward provision of one of these services. Many C-sequestering management practices can also assist pastoralists adapt to the impacts of climate change, a theme attracting increasing international funding. Other financing approaches exist that may reward provision of other services, such as conservation banking and other forms of payment for ecosystem services. Existing examples include payments for ecosystem services in silvopastoral land use systems in Latin America, in which payments are made for a range of environmental services provided by silvopastoral management practices, including carbon and biodiversity (Pagiola et al 2004).

5.3 Ways forward

Compared to other markets for ecosystem services, there is strong demand globally for further development of carbon markets. This is driven by growing awareness of the huge future costs if GHG emissions are not abated (Stern 2007). It can be expected, therefore, that carbon markets will develop more rapidly and with deeper financial backing than other regulatory or market mechanisms. Carbon assets also have co-benefits for many other environmental services. There are, therefore, strong reasons for further exploring the development of rangeland carbon assets. Here, we point to some broader initiatives required and make specific recommendations to promote the development of rangeland carbon assets

Trust Fund for pilot projects High initial costs will be incurred by the early rangeland carbon sequestration pilot projects, which have to invest in the development of a methodology as well as other start-up costs. The cost of subsequent projects will be lower. This would seem to justify some public investment in these early pilot projects. At the same time, the development of carbon finance projects is a learning by doing process. General training and capacity building initiatives mostly fail, particularly in Africa, because they do not target project developers who play a key role in linking carbon assets to markets, and because training is rarely linked to the supply of carbon finance. One successful approach to develop carbon finance projects is by establishing a Trust Fund with the objective of developing a number of pilot projects around a particular theme. The Trust Fund should be big enough to develop a cluster of projects in one region so as to facilitate close interaction between project developers and facilitate learning from available expertise. Capacity building of stakeholders for engagement with carbon markets should be undertaken in interaction with sources of carbon finance, not as isolated training exercises. A public-private Trust Fund investment vehicle would be appropriate for achieving this.

Recognizing the relevance of rangelands in national GHG accounting systems Rangelands are the largest land use type, covering around 40% of the world's land surface, with significant presence on all continents (White et al 2000). In 28 countries, mostly in Africa, rangelands cover more than 60% of land area (ibid.). Smith et al (2007) estimate that the emissions mitigation potential of global agriculture up to 2030 lies between 1500 and 4500 MtCO_2e depending on climate change and carbon market scenarios. Improved rangeland management has a biophysical potential to sequester 1300-2000 MtCO_2e, depending how rangelands are defined (ibid.). Continued degradation of rangelands worldwide has clear impacts on the global provision of essential environmental services and global climate system. The importance of rangelands should receive better recognition in the current climate change mitigation and adaptation policy development process. In some countries such as Australia the importance of rangeland carbon fluxes is already recognised. But in most other countries, e.g. in Africa or China, more science-based advocacy work is required to integrate rangeland management into climate policies.

In order to better understand the contribution of rangelands to global change, national GHG accounting systems for terrestrial carbon, including rangelands, are required. These can set a baseline for prioritizing sources of mitigation and targeting the design of programmes to reward herders for mitigating CO_2 emissions at national or sub-national level.

Improved knowledge of the role and importance of rangelands in different countries' GHG budgets should also be linked to international discussions on the inclusion of terrestrial carbon in intergovernmental climate regimes.

Refining and communicating the state of the art A considerable and growing body of knowledge on the impacts of management practices on rangeland C sequestration already exists. Rangeland policy makers and managers in many countries, as well as key actors in the carbon finance sector, have relatively little awareness of the potential of rangeland carbon sequestration. Much existing data is not available in accessible forms.

Conant et al (2001) is still the main database informing global estimates of rangeland C sequestration potential. For grazing management, that database includes only data on 'moderate' grazing levels, which is inappropriate in situations where soil C accumulation responds positively to either light or heavy grazing. The database should be revised and updated.[20] There is very little existing data on costs of rangeland mitigation activities, which makes it difficult to realistically assess the potential for adoption. The increasing knowledge base on the impacts of climate change should also be incorporated. The WOCAT database on soil conservation approaches (www.wocat.net) provides one model for facilitating access to state of the art knowledge on rangeland C sequestration approaches and techniques. This can aid practitioners to identify best rangeland management practices, as well as providing information for more targeted policy briefs.

Carbon and pastoralists' land rights Perverse outcomes where carbon finance projects do not mitigate additional CO_2 from the atmosphere and/or have adverse impacts for the people involved in the host country have to be prevented. In many countries, rangelands are misunderstood as under- or non-productive lands, and pastoralism seen as backward, of little economic value, and often also environmentally destructive. In this context, there is a risk that pastoralists' grazing rights are significantly altered in the framework of rangeland carbon finance projects. Activities to improve understanding of the value of rangelands and pastoral economic systems (e.g. Rodriguez 2008), to support pastoralists to maintain mobility in rangeland ecosystems, and to strengthen their land tenure and land rights, may well prove to be very relevant in the context of a growing carbon market.

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[20] A special issue on grazing and GHGs of Rangeland Ecology and Management due for publication in autumn 2008 may contribute more up-to-date synthesis.

Appendix 1: Data used in the analysis of biophysical potential

Several estimates of the global C sequestration potential of rangeland management practices draw on a database constructed by Conant et al (2001). For the purpose of this paper we have made the following adjustments to that database:

1) Because the focus of this paper is on C sequestration potential in extensive livestock systems, we have deleted data points in the Conant et al (2001) database which derive from research in highly intensive production systems in the UK, Netherlands and France. We have retained data points from the USA, Australia and New Zealand where extensive grazing takes place in the context of otherwise intensive systems (e.g. high levels of energy and fuel use).
2) We have added 41 data points that were not included in Conant et al (2001) either because they were published after that paper or because they were omitted from that paper. There are many more reports in the recent literature than the 41 that we have included. These 41 data points were selected because they report results of long-term chronological (before-after comparison) studies, rather than the results of comparisons between different land use types which are common in the literature.

The result is a preliminary database containing 304 data points, of which 263 derive from Conant et al (2001). The table below shows that, despite its importance to global rangelands, Africa is greatly underrepresented. This is due to the relatively little amount of relevant research done there as well as to the sample of data points chosen from the literature.

There is clearly a need to further revise the database to include all available reports, and also to correct the treatment of data in the Conant et al (2001) database so that it is better suited for interpretation in the context of carbon finance.

Country of origin of C sequestration database data points

Americas	Africa & M. East	Asia & Oceania
Argentina (n=4)	Saudi Arabia (n=2)	Australia (n=63)
Brazil (n=31)	Tanzania (n=1)	New Zealand (n=40)
Canada (n=41)	Uganda (n=1)	China (n=9)
Colombia (n=23)	Zimbabwe (n=3)	
Costa Rica (n=10)	Burkina Faso (n=1)	
Mexico (n=4)	South Africa (n=2)	
USA (n=69)		

The revised preliminary database is available from the second author (a.wilkes@cgiar.org) upon request. The original database of Conant et al (2001) is available from the Ecology Society of America's Electronic Data Archive: Ecological Archives A011-005.

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Who we are

The World Agroforestry Centre is the international leader in the science and practice of integrating 'working trees' on small farms and in rural landscapes. We have invigorated the ancient practice of growing trees on farms, using innovative science for development to transform lives and landscapes.

Our vision

Our Vision is an 'Agroforestry Transformation' in the developing world resulting in a massive increase in the use of working trees on working landscapes by smallholder rural households that helps ensure security in food, nutrition, income, health, shelter and energy and a regenerated environment.

Our mission

Our mission is to advance the science and practice of agroforestry to help realize an 'Agroforestry Transformation' throughout the developing world.

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