RANGELANDS AS A SINK FOR CARBON

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Contents

Summary

This chapter has several sections. In the first section the international context is elaborated and the role of anthropogenic factors is highlighted. The potential and actual carbon storage capacity of rangelands is reviewed. The world's drylands have the potential to sequester about 1.5 Gt of carbon each year if all were restored to their ecological potential. The economic linkage between fossil fuel burning is explained, including carbon-offsets and the problems of validating carbon capture and storage. The role that carbon offsets can play in funding rangeland rehabilitation is discussed. Experience from China's alpine meadows is reviewed and data from several studies are summarized. Grazing impacts on the carbon sink are highlighted, as is the beneficial effects of fencing as a management tool to allow rangeland regeneration.

Growing halophytes in deserts (with saline waste water) or in coastal deserts is a

successful approach for capturing and storing carbon and for improving supplies or fodder for livestock and for feedstock for the production of ethanol as part of the push to promote biofuels. A conservative estimate of land available for irrigated halophyte production is 1,250,236 km^2 (approximately 1.25 x 10^8 ha). This acreage would expand current world irrigated agriculture land by 50%. With a biomass yield of 10 t/ha/yr and ethanol yield of 190 l/t, halophyte biofuel crops could produce 237 billion L of ethanol per year.

1. The International Context

Increased concentrations of greenhouse gases have led to global concern that human activities could lead to accelerated changes in climate patterns. The major anthropogenic sources of greenhouse gas emissions are combustion of fossil fuels (5.5 billion tons carbon per year) and land use change (1.6 billion tons carbon per year. The Fourth report of the Intergovernmental Panel on Climate Change, released in 2007 found that “the balance of evidence suggests a discernible human influence on global climate” and that “Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level……”

The concern about the greenhouse effect is of course that the increasing emissions of greenhouse gases (GHGs), e.g., carbon dioxide, methane, nitrous oxide and chlorofluorocarbons (CFCs), resulting from human activities may cause a rise in global-mean surface air temperature or induce "global warming". Both natural (e.g., solar variability, volcanic eruptions) and human (e.g. combustion of fossil fuels, agricultural practices and deforestation) activities can affect climate change by modifying the emissions of greenhouse gases, aerosols and their precursors. The rates of increase in the atmospheric concentrations of carbon dioxide and nitrous oxide have continued to grow or remain steady while those of methane and some halocarbon compounds have slowed.

Land use change and degradation are important sources of greenhouses gases globally, responsible for about 20% of erosion. Land degradation leads to increased carbon emissions both through loss of biomass when vegetation is destroyed and through increased soil erosion. Erosion leads to emissions in two ways: by reducing primary productivity, thereby reducing soil’s potential to store carbon and through direct loss of stored soil organic carbon (SOC). Although not all carbon in eroded soil is returned to the atmosphere immediately, the net effect of erosion is likely to be increased carbon emission.

The potential impacts of climate change and global warming are numerous and we do not need to elaborate them here.

In response to the threat of climate change more than 190 countries, have become parties to the United Nations Framework Convention on Climate Change (FCCC). The objective of the Convention is:

> "to achieve … stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."

The emission of the greenhouse gas CO_2 to the atmosphere continues to escalate (Figure 1). Coal, gas and petroleum-fired electric power stations account for one-third of the global fossil fuel C emissions. Estimates of annual emissions of CO_2 by fossil fuel and land use change for the period 1980 to 1989 are 5.4 ± 0.5 Pg of C per year and 1.6 ± 1.0 Pg of C per year, respectively. Global oceans are estimated to absorb 2.0 ± 0.8 Pg of C per year, and about 3.2 Pg per year remains in the atmosphere. This calculation leaves an amount of 1.8 ± 1.4 Pg per year unaccounted for -- the so called "missing" CO_2.
It is generally accepted by the IPCC that during the decades of the 1980s and 1990s that global terrestrial ecosystems absorbed Carbon at the rate of 1-4 Pg /yr, offsetting 10-60 % of fossil fuel emissions.

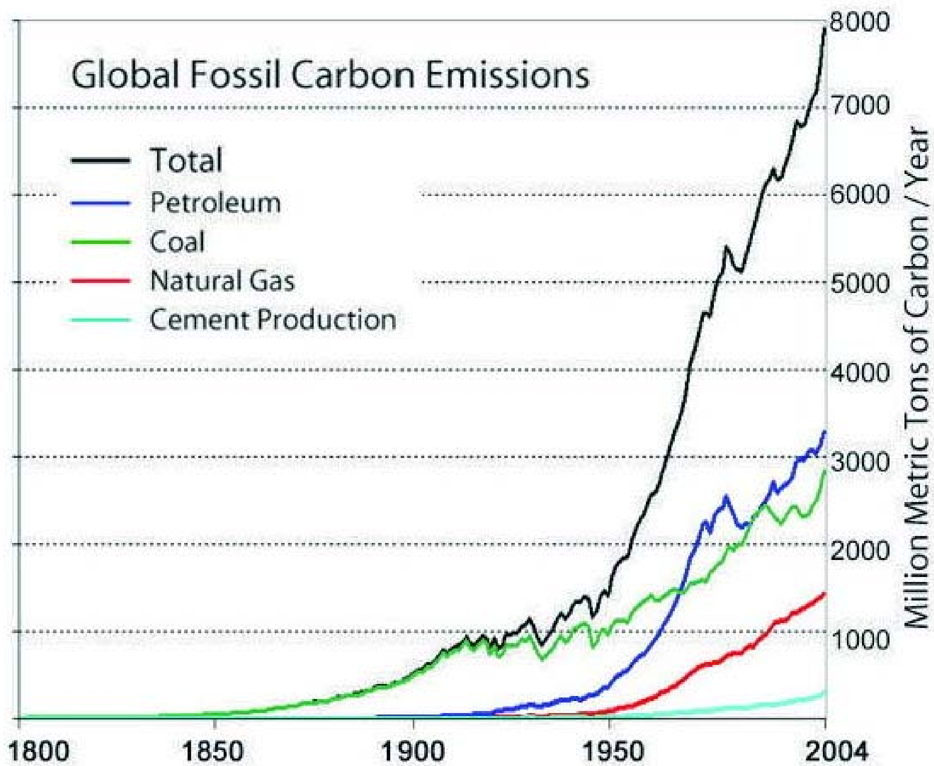

Figure 1. Global carbon dioxide emissions to the atmosphere (by source)

1.1. Potential and Actual Carbon Storage Densities of the Drylands

The extent of land degradation in the drylands (many of which are rangelands) has already been estimated. These estimates lack sufficient detail to be used as management tools at a local level, but they are sufficient to estimate the amount of land degradation that has occurred at a regional or continental scale. Unfortunately land degradation is not defined in terms of carbon storage but is estimated by degree of soil erosion and reduction in above ground net primary productivity. Nevertheless, important calibrating studies on several continents, covering a range of dry agro-ecosystems, have established relationships between carbon storage and net primary productivity. These calibrating studies are used to estimate the difference in net carbon storage in degraded compared to the restored and sustainably-managed dry rangelands across the dryland areas of the globe. The estimates are used to project net changes in dryland carbon storage over the next 50 years under two scenarios: 1) business as usual (continuing land degradation over 50 years); 2) implementation of major elements of the Action Plan to Combat Desertification under the UNCCD. The phase-in of the Action Plan is assumed to occur over a 20 year period. The costs of implementation have already been estimated. These may be used to estimate the costs of carbon sequestration by improving land use practices in the drylands compared and compared to other carbon offset costs (see 1.6 below).

Carbon storage estimates use multiple sources of information to be compared and contrasted in order to assess the validity and sensitivity of the estimates. The data types will include: remote sensing studies; ground studies; long-term monitoring studies in natural and disturbed dryland areas; soil carbon measurements; and modeling studies. Studies of wide geographic distribution and in as many different ecosystems as possible are used. This approach produces estimates of carbon storage that will include a range of values, indicating the degree of uncertainty of the estimates.

1.2. Rationale for Sequestering Carbon in Drylands

At first glance, the possibility of large-scale carbon sequestration on drylands might seem unlikely. Compared to other biomes, drylands accumulate only a fraction of the hundreds of tons of carbon per hectare that can accrue in temperate and tropical forest systems, and at a fraction of the annual rate. But the world's drylands store about 241 Pg of organic carbon, 60 times more than is added to the atmosphere annually by fossil fuel burning.

The principal biological sinks for CO_2 were thought to be the forested regions of the world, notably tropical rainforests, and much effort has been concentrated there. It is now clear that drylands are also a prime candidate for a major carbon sequestration effort. Any effort to sequester a large number of tons of atmospheric carbon on drylands must surely involve significant challenges -- scientific and organizational. But these are challenges that humankind must face as the twenty-first century unfolds.

Not the least of these challenges is to find enough land. To absorb even 25% of the atmospheric CO_2 emissions into dryland soil and vegetation would require an area of about 2 to 5 billion hectares (ha). But most dryland is under human management and if incentives such as carbon trading schemes and the acceptance of carbon offsets (see Section 1.4 below) were provided the management system could be altered to sequester more carbon.

Estimates have been made of the potential productivity of the world ecosystems based on the type of native vegetation they supported before human land-use systems were imposed on them. Productivity is very low in the desert regions (approximately 25 g C $/m^2$ /yr), but increases in the arid and semi-arid areas, reaching levels as high as 400 g C $/m^2$ /yr in the dry tropical forests. These rates are nearly as high as productivity rates in the temperate regions.

Increasing carbon storage in the dryland areas will involve converting degraded lands, which are performing well below their potential, into land-use systems that perform closer to the production levels in undisturbed ecosystems. Obviously, the greatest potential for carbon storage lies in the regions with the highest potential productivity, while the deserts have little potential for increased carbon storage but even deserts can absorb and immobilize carbon through methane oxidation.

1.2.1. Methane Oxidation in Desert Soils

All well-aerated undisturbed soils including very dry desert soils not subject to nitrogen fertilization oxidize methane at a low rate, It has implications for 1 billion ha globally of hyper arid lands. It also applies to much of the remaining 5.2 billion ha of drylands. Whereas there is no direct carbon uptake, methane uptake of 1-30 kg/ha/yr (equivalent to 5-150 kg C/ha/yr), can occur indefinitely. The existence of the oxidative sink has been demonstrated by several scientists. The benefit is direct and simple, and it happens anyway. But the process is sensitive to nitrogen deposition. There are no social, political or economic risks. There are no operational costs. There would be significant validation costs if carbon offsets were claimed so it is unlikely that methane oxidation will enter into any carbon trading arrangement but it will occur nonetheless.

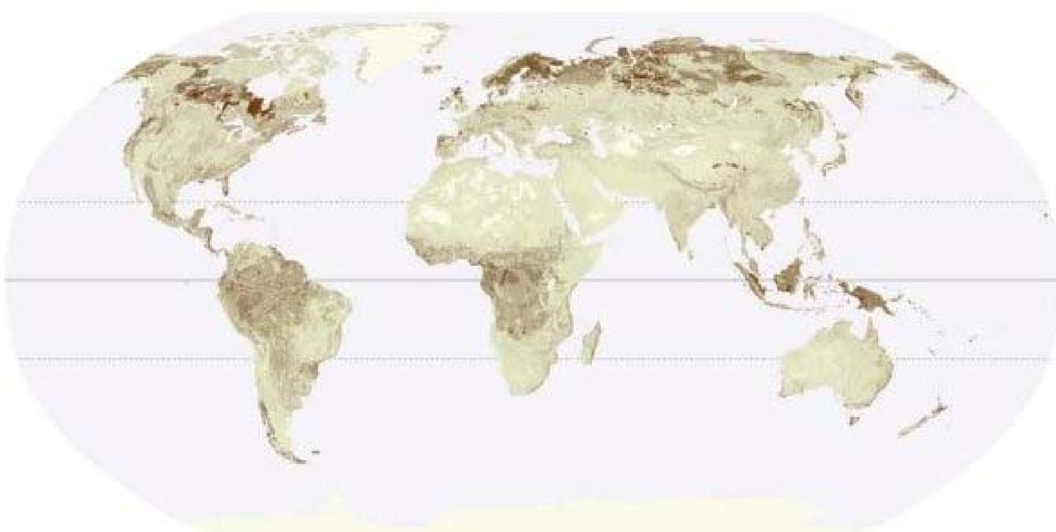

Figure 2. Map of world deserts

Rangelands and adjacent desert lands have the potential to be a sink for significant amounts of carbon, especially if they are restored to their ecological potential. It is likely that the natural biomes (deserts, grasslands, woodlands, tundra and forests) are already participating in increased storage of a fraction of the carbon from fossil fuel emissions, although physical evidence for this is scant.

Restoration of the world's drylands would have a major impact on global climates since the world's drylands (excluding the hyper-arid regions) cover 5.2 billion ha and have the potential to sequester 0.5-1.0 Pg C /yr. The huge cost of arid land rehabilitation could be provided via privately funded carbon offsets programs and special efforts to sequester carbon in the world's deserts and adjacent drylands (see 1.4 below).

There is an opportunity for mitigation of the rate of increase of atmospheric CO_2 through absorption and storage of carbon in plant and soil (carbon sequestration). Carbon sequestration is the process of carbon stock aggradation and may be viewed as a key to reverse land degradation. Carbon sequestration is not the carbon stores themselves, but increases in those pools for substantial periods of time as a means of offsetting atmospheric changes.

	MITIGATION OPPORTUNITIES RELATED TO DEGRADATION	
Issues	***Maintenance*** Avoid losses of C	***Capture*** Seek gains of C
Physical	Do changes in system state cause loss of C?	Is there a system change resulting in C sequestration?
Ecological	How vulnerable to change is the system? Are changes irreversible?	Is the system change biologically achievable?
Socioeconomic	Are there pressures for management changes which will degrade the current system?	What cost is there to changing the system, and is the outcome acceptable socially?
Cultural	Is the current management culturally acceptable?	Is the management needed for the change culturally feasible?

Table 1.General questions Related to Mitigation Opportunities in Arid Lands.

Mitigation strategies involve one of two options (Table 1):

1) To conserve and/or protect existing carbon sinks (Photo 1)
2) To increase the capacity of the land to sequester carbon (Photo 2)

Given that drylands seem to represent a sufficient potential opportunity for carbon sequestration that further analysis is worthwhile, two steps should be undertaken to properly identify and assess specific regional opportunities:

1. A comprehensive, iterative procedure for identifying what land use/ecosystem changes would preserve or capture carbon stocks; this procedure should be applied in a superficial fashion to major land use/ecosystems around the world, to highlight those options that have promise. It involves identifying what managed states each land use/ecosystem may be in, what the transitions between these states mean for carbon storage, and then assessing biophysical, socio-economic and cultural/political constraints in relation to transitions that are positive in terms in carbon storage (Fig.2). This analysis should be applied to a suite of systems that represent different climate, soil and social conditions.
2. A second comprehensive procedure should be applied to promising options to determine whether they show sufficient returns, credibility, low risk, and ancillary benefits to be considered by a public or private donor source, and, if so, for what principal reason.

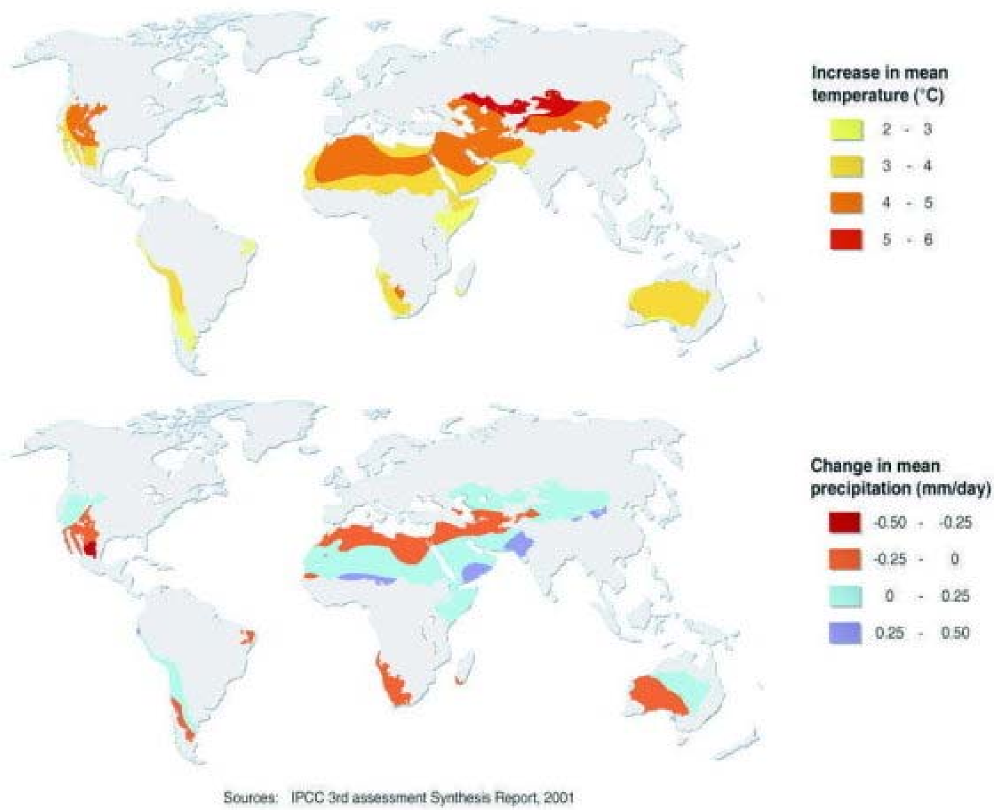

Figure 3. Projected temperature and precipitation changes

Photo 1. Well managed vegetation on drylands can be an important sink for CO_2. Good management is the key to conserving C storage capacity.

Photo 2. Revegetation of degraded drylands can do much to improve the rate of C sequestration.

Actions that can be taken to accelerate storage of carbon in the terrestrial biosphere may be relatively low cost and thus may partially offset some of the emissions from fossil fuel burning. Small unit changes in the rate at which carbon is emitted or sequestered in these soils can have relatively large impacts on the atmospheric carbon budget, given the large areas of drylands. Drylands cover 6.1 billion ha worldwide, 5.2 billion ha of which are arid, semi-arid or dry sub-humid lands capable of supporting some form of agricultural or pastoral production. Thus they cover more than one-third of the world's total land area, a greater portion than is covered by cropland (1.4 billion ha) or closed forest (4.4. billion ha).

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Biographical Sketches

Dr. Victor Squires is an Australian, a former Dean of the Faculty of Natural Resources at Adelaide University and the Foundation Director of the National Key Centre for Dryland Agriculture and Land Use Systems. Dr Squires is an Adjunct Professor in the University of Arizona, USA. He is an internationally well known environment expert who has conducted many projects in multiple sectors of environment protection, natural resource and biodiversity conservation, land degradation and desertification control. He has worked in many developing countries e.g. China, Mongolia, Thailand, Algeria, Ethiopia, Iraq, He has a background in teaching and applied research and holds a Ph.D degree in Natural Resources Management, a Masters Degree in Ecology and Botany, and Bachelors degrees in Botany and Geography. As an educator he taught undergraduate and post graduate students in Australia, and conducted applied research and training programs for institutions and government agencies over the world.

Dr. Ed Glenn is a Professor in the Environmental Research Laboratory of the /university of Arizona, Tucson, USA. He did his PhD in Marine biology at the University of Hawaii and has always had an interest in the problems of soil and water salinity, especially the physiological aspects that affect plant growth. He pioneered a lot of the work on saline water irrigation in coastal deserts in Mexico, the Arabian Gulf countries. His interest in carbon offsets and how to utilize the drylands has been a continuing one. Dr Glenn was joint convenor of two important UNEP-sponsored International Symposia about *Halophytes as resource for livestock and for rehabilitation of degraded lands* and *Combating global by combating desertification* He is author of over 100 scientific papers.

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