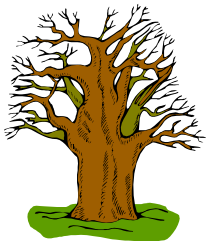
# Soil Carbon Sequestration in Semi-Arid and Sub-Humid Africa



## Carbon Emissions and Climate Change

Human activities, such as the burning of fossil fuels, deforestation, grassland conversion, and other land use changes, have contributed to a large atmospheric increase in **carbon dioxide ($CO_2$)** and other greenhouse gases over the last hundred years. Most scientists believe that this rapid $CO_2$ accumulation in the atmosphere will result in climate change, particularly **global warming**. Although it is not yet possible to accurately predict the consequences of global warming, most experts agree that if this trend continues, the global consequences might be substantial. **Africa**, the continent arguably **most vulnerable** to the impacts of predicted changes, is likely to face higher interannual variability of rainfall, more extreme climate events, such as floods and droughts, and, in dryland areas already severely afflicted by land degradation, irreversible desertification.

**This brochure** is the result of the 1999 international workshop "Carbon Sequestration in Soils and Carbon Credits: Review and Development of Options for Semi-arid and Sub-humid Africa" (http://edcintl.cr.usgs.gov/ip). It stresses the role of soil carbon sequestration in the mitigation of climate change and the potential environmental and societal benefits for Africa. It also proposes approaches for project implementation.

## Carbon Sequestration: A Possible Mechanism for Climate Change Mitigation

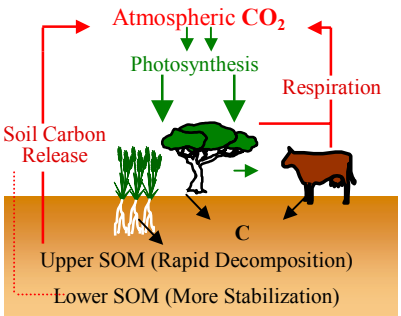
### ◆ What is Carbon Sequestration?

Carbon exists in various chemical forms in five distinct reservoirs or pools: the atmosphere, the oceans, the terrestrial biomass, soils, and geologic formations. These pools are interconnected, allowing a continual redistribution of carbon among them. Oceans and geologic formations contain the highest amounts of carbon. **Soil organic carbon** is a large and active pool, containing roughly twice as much carbon as the atmosphere and 2.5 times as much as the biota. **Carbon sequestration** is the facilitated redistribution of carbon from the air to other pools. This will reduce the rate of atmospheric $CO_2$ increase, thereby mitigating global warming.

### ◆ How does Soil Carbon Sequestration Work?

Carbon sequestration in soils is based on the assumption that fluxes or movements of carbon from the air to the soil can be increased while the release of soil carbon back to the atmosphere is decreased. Instead of being a **carbon source**, soils could be transformed into **carbon sinks**, absorbing carbon instead of emitting it. This approach relies on the main natural processes that control the carbon cycle: **photosynthesis**, through which carbon from the air is converted into organic material, and **respiration**, through which carbon is returned to the atmosphere.

Picture: Anthony Young

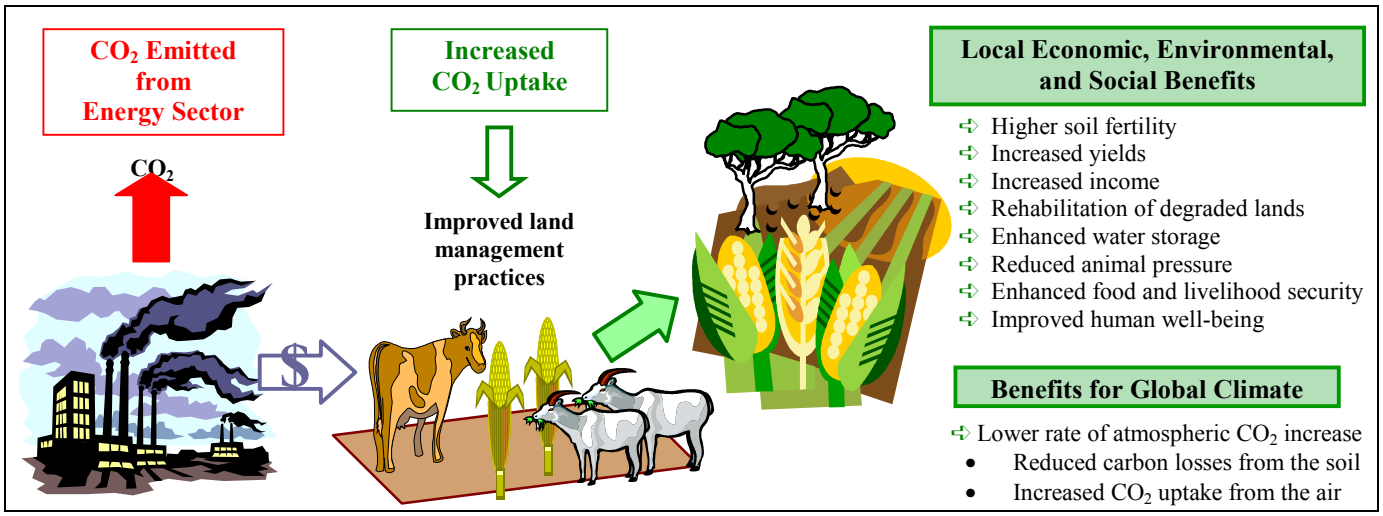



### ◆ The Soil Carbon Cycle

Carbon enters the soil as roots, litter, harvest residues, and animal manure. It is stored primarily as **soil organic matter** (**SOM**). The density (w/v) of carbon is highest near the surface, but much of the recent SOM decomposes rapidly, releasing $CO_2$ to the atmosphere. Some carbon becomes stabilized, especially in the lower part of the profile. Balanced rates of input and decomposition determine **steady state fluxes**. However, in many areas, agricultural and other land use activities have upset the natural balance in the soil carbon cycle, contributing to an alarming increase in carbon release.

## Carbon Sequestration: A Win-Win Strategy

Carbon sequestration in soils has direct advantages for the people who manage this carbon pool. Improved land and soil management practices can yield **economic, environmental, and social benefits for local populations** and, at the same time, **contribute to climate change mitigation**.




## Africa's Role in Soil Carbon Sequestration and Climate Change Mitigation

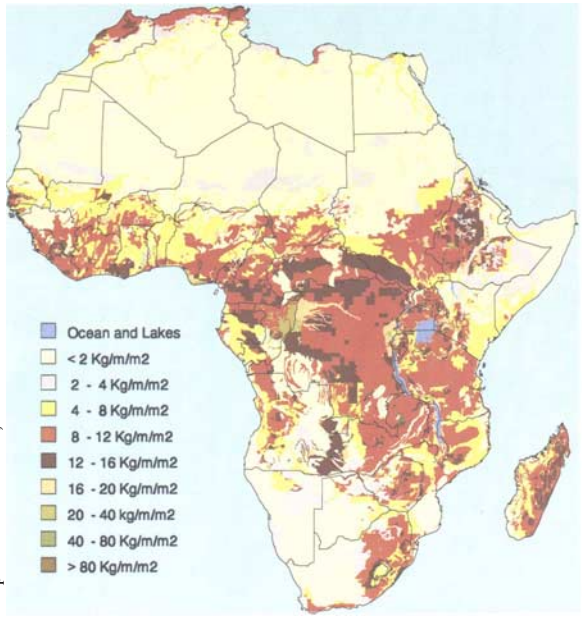
Most African countries rank very low among the global emitters of $CO_2$ from fossil fuel burning and, therefore, have played only minor roles in international projects preventing global warming. However, many experience alarming rates of declining soil carbon, soil quality and fertility due to land degradation and desertification. Soil carbon sequestration would permit African countries to **proactively participate** in and **benefit** from global change mitigation, simultaneously addressing three important international conventions: The Convention on Climate Change, The Convention to Combat Desertification, and The Convention on Biological Diversity.

### The Carbon Sink Function of Degraded Semi-arid and Sub-humid Lands in Africa

Some scientists suggest that the **highest potential** for soil carbon sequestration can be found in degraded lands including the **semi-arid and sub-humid regions** of Africa. Due to a combination of increasing population and animal densities, overcultivation, extensive fuel-wood gathering, and overgrazing, as well as unfavorable economic and agricultural policies, these regions have been experiencing critical **losses of biomass** and a **decline in biodiversity and productivity.** Degraded lands not only have exhausted most of their capacity to sequester carbon but also have emitted a substantial amount of $CO_2$ from the soil to the atmosphere, thereby contributing to the greenhouse effect and global warming.

**Carbon sink management** – improved dryland farming, rangeland management, and irrigation – could reverse this trend by replenishing depleted soil carbon stocks. It is the rehabilitation of degraded areas through successful carbon sink management that is at the heart of soil carbon sequestration for local, societal, and global benefits.

**Soil Organic Carbon in Africa**




Graphic: Pam Waisanen, Data: USDA/NRCS

# Land Management Options for Soil Carbon Sequestration

## ◆ How to Replenish Depleted Soil Carbon Stocks?

Agricultural and other land use practices have a significant influence on how much carbon can be sequestered and how long it can be stored in the soil before it is returned to the atmosphere. The best strategies focus on the protection of soil organic carbon against further depletion and erosion or the re-accumulation of depleted carbon stocks through certain management techniques. In either case, **the keys** to **successful soil carbon sequestration** are **increased plant productivity** — increased net primary production — and **decreased decomposition**.

## ◆ Example Options for Semi-arid and Sub-humid Lands

Picture: Petra Tschakert

- increased fallow periods and crop rotation
- reduced tillage
- application of crop residues and litter
- mulching and green manuring
- direct application of compost and manure
- improved water conservation (micro-catchments)
- erosion control (shelterbelts, ditches, grass cover)
- agroforestry (mix of trees, shrubs, crops, pasture, and animals in rotation or next to each other)
- irrigation and use of chemical fertilizer and pest control
- conversion of marginal agricultural land to rangeland
- restoration of grasslands and savanna systems

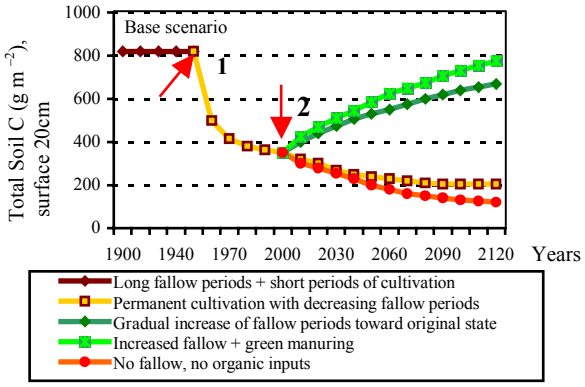
## ◆ How to Find the Ideal Mix?

The choice of the most efficient land management practices for soil fertility improvement and carbon sequestration depends on two essential parameters: the **ecotechnological potential** and the **socioeconomic incentives**. In many cases, successful projects will to include a **tradeoff** between what is technically feasible, economically desirable, and socially acceptable.

### Assessing the Ecotechnological Potential

Local agroecological parameters, such as climate, soil characteristics, and land use practices, determine the ecotechnological potential for carbon sequestration. Since any change of carbon in SOM is linked to the inorganic nutrient status — the fertility — of the soil, technical management options should always consider appropriate nutrient ratios (nitrogen, potassium, etc.).

**Example of Management Effects on Soil Carbon**




### Assessing the Socioeconomic Incentives

African countries are unlikely to engage in soil carbon sequestration unless there are clear local economic and societal benefits. Therefore, it is essential to carefully **estimate all potential costs and benefits** related to the various management options. Large-scale adoptions of ecologically sound land use practices are likely to be the most cost effective and environmentally friendly option to increase soil carbon sequestration in Africa.

Potential Costs:

- direct costs for agricultural inputs, transportation, labor, monitoring, and measurement
- indirect environmental, resource, and other costs
- opportunity costs or the foregone benefits from other types of land use

Potential Benefits:

- increased agricultural output and local income
- reduced risk for crop failure
- improved environmental conditions
- enhanced food and livelihood security

## Carbon Emission Reduction Credits

The **Clean Development Mechanism** (CDM), proposed in Article 12 of the **Kyoto Protocol** to the United Nations Framework Convention on Climate Change, will allow developing countries to sell or trade **project-based carbon credits,** such as Carbon Emission Reduction Credits (CER credits), to or with industrial countries, if adopted. CER credits could provide an incentive for participation in climate change mitigation and cover the costs that African participants will encounter when engaging in carbon sequestration.

For instance, they could authorize $CO_2$ emitters, such as a private utility company, to pay African farmers and herders for modifying their existing land management strategies in ways that will increase the amount of carbon sequestered. This amount could offset some of the carbon the utility company would have added to the atmosphere and, if correctly measured and verified, would be reflected in the size of the credit.

Ideally, the CDM could provide desirable capital to African countries for the sustainable use and conservation of their natural resources and urgent societal needs. At the same time, **African partners** could position themselves to become **major carbon sellers** to industrialized countries.

## Integrative Approaches for Project Implementation

Since the mitigation of climate change is a global task, it requires both **international and local contributions**. Successful carbon sequestration projects involve the choice of most appropriate management strategies, based on an area's eco-technological and socioeconomic potential, as well as the active participation of local populations. **Complementary and dynamic approaches**, such as the ones shown below, are most promising.

### Remote Sensing

Remotely sensed imagery allows assessment of historical land use changes and identification of degraded lands within semi-arid and sub-humid ecosystems that, technically, have a high potential for sequestering carbon. It helps to elucidate changes in the carbon balance over time and to establish a quantitative potential for carbon sequestration in each ecosystem.

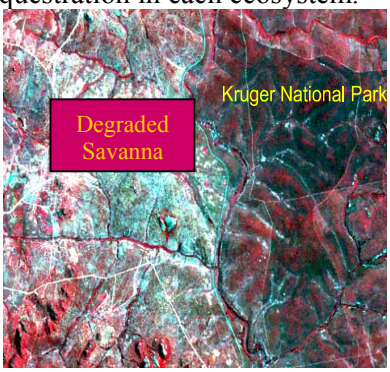



Image source: Dirk Pretorius (LandSat TM)

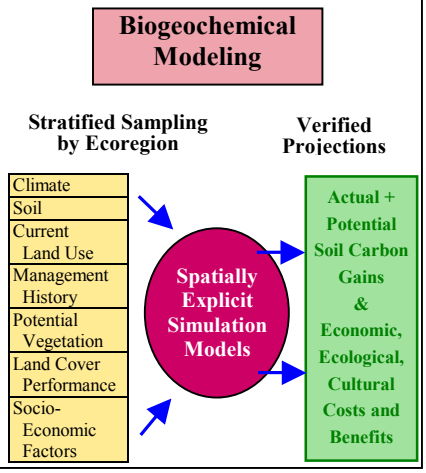
### On-the-Ground Assessment

Picture: Petra Tschakert

Carbon sequestration needs to be integrated in existing social structures. It is imperative to assess local soil management practices that can be promoted and (or) improved and to evaluate locally respected institutions through which carbon credits can be distributed. Local cooperation is also needed to start site-level monitoring and measuring of net carbon gains.

### Simulation Modeling

Simulation modeling is used to assess carbon sequestration gains, as well as environmental and economic benefits of various soil and land management scenarios. Simulation outcomes are then validated with the results from ground assessments.





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| **For more information, please contact:** | Larry L. Tieszen, Ph.D.<br>Deputy Manager, International Programs<br>EROS Data Center, USGS<br>Sioux Falls, SD 57198 USA | tieszen@edcmail.cr.usgs.gov<br>http://edcintl.cr.usgs.gov/ip<br>Phone: 1 (605) 594-6056<br>Fax: 1 (605) 594-6529 |



**Supported by:** USAID and Bradley Fund for the Environment of Sand County Foundation