South Dakota

NO-TILL

Association

No Till: The "C" Connection

Crossroads Hotel and Convention Center

Huron, South Dakota

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Carbon is the "C" that starts "C"onservation

D.C. Reicosky[1]

[1]Soil Scientist, USDA-Agricultural Research Service, North Central Soil Conservation Research Laboratory, 803 Iowa Avenue, Morris, MN 56267; Phone: +1-320-589-3411 x 144; Fax: +1-320-589-3787; reicosky@morris.ars.usda.gov

Abstract

The time has come for a shift in our conservation concepts and programs to get away from the stale approach of managing for only erosion control and move to managing for soil carbon(C). We need to move to the next level of conservation by shifting our focus to managing for both erosion control and soil C for soil quality. The soil is the fundamental foundation of our economy and our existence. While soil erosion continues to be a major problem, we must expand our thinking to address related soil quality issues, which translates to soil C. Carbon management is required to address a complex list of issues including soil, water quality, biofuel, and climate change. The current concern about possible global change and management options elevates the importance of C management and conservation. Thus to maintain sustainability of the soil resource, we must think about soil C management and make efforts to maximize C input and minimize C loss. Today, we must place more emphasis on conservation of all natural resources and additional emphasis on C as a key component in maintaining ecosystem stability.

Key Words: soil carbon, soil organic matter, soil quality, environmental quality, zero tillage, direct seeding, carbon sequestration

Introduction

World soils serve as an important pool of active carbon (C) and play a major role in the global C cycle and contributed to changes in the concentration of greenhouse gases in the atmosphere. Society must be dedicated to investigating and protecting our global soil resources for the expanding population. The soils are the fundamental foundation of our society with soil C as one of the critical components. Agriculture has a finite amount of land suitable to support the increasing global population requiring food production systems with increasing capacity. The earth's surface area is 71% oceans and 29% land area with only about 14% of the total land area(~1,982 Mha) suitable for crop production. The scientific community has an important challenge in addressing C management of our land resources essential to ensuring food security of the expanding world population. The objective of this work is to clarify the role of C in conservation and how C management can lead to sustainable production.

Our challenge is to understand the relationship between soil C and soil organic matter (SOM) as they impact soil conservation. Soil organic matter is something we can visualize, measure, manipulate, touch; however, there are many misconceptions about SOM. Soil organic matter is the small fraction of the soil matrix, composed of anything that once lived and includes all the organic substances in or on the soil (Figure 1). It includes plant and animal remains in various states of decomposition, cells and tissues of soil organisms, and substances from plant roots and soil microbes. Soil organic matter refers to the sum total of all organic C-containing substances in the soil. Soil organic matter consists of a mixture of plant and animal residues in various stages of decomposition, substances synthesized microbiologically and/or chemically from the breakdown products, and the bodies of live and dead microorganisms and their decomposing remains. The main chemical element in all of these components is C, and as a result the terms SOM and C are often used synonymously.

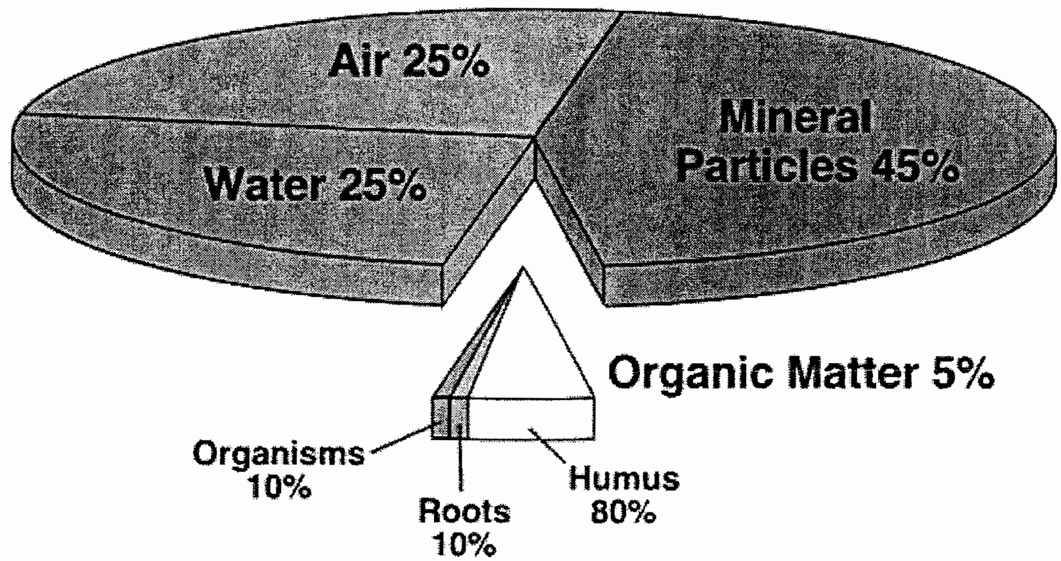

Figure 1. Most soils contain four basic components: mineral particles, water, air, and organic matter. Organic matter is about 58% C and can be further sub-divided into humus, roots, and living organisms. The values given above are for an "average" agricultural soil.

Soil Conservation Concepts – Erosion and Water

Words can have a magical power for transferring knowledge. The proper selection of the words can arouse the strongest emotions resulting in prompt action. Conservation is one of those words that relates to environmental issues associated with moral values, social and economic justice and the well-being of all people. Conservation is a man-made concept concerned with how man relates to his land and uses its resources. Conservation is a moral concern, a personal virtue, a political issue; but anyway you say it, conservation is necessary. To some people, conservation is simply erosion control. Erosion is another word that arouses emotions because it brings visual perception of soil loss, wind blown drifts, deep gullies and muddy waters. Soil erosion causes loss of topsoil, decreased soil organic C, lower available water and nutrient holding capacity, decreased soil health and reduced yield and increased spatial variability. More management skills and equipment are required to cope with the consequences.

Agriculture worldwide is causing serious soil losses as illustrated in figure 2. The impacts of these four types of erosion are the unintended consequences of intensive tillage in agriculture that can be addressed by better C management. If the destruction of agricultural soils continues in the same way, humans might face serious problems feeding a growing population. There are different causes for this inadequate use of the soil. In many developing countries hunger is forcing poor people to cultivate areas which are not suitable for agricultural use and which only with major and costly efforts, like the construction of terraces, can be sustainably converted into agricultural land. Soil loss through erosion is only part of the problem as a consequence of the way agricultural soils are treated in mechanized agriculture. The loss of rain water that cannot infiltrate in the soils to replenish the ground water reserves might in the long-term be the more serious problem. Consequently, the way soil is cultivated must be drastically changed. Soil erosion and water loss are not only controlled by mechanical means but also by a living and stable soil structure that depends on soil C.

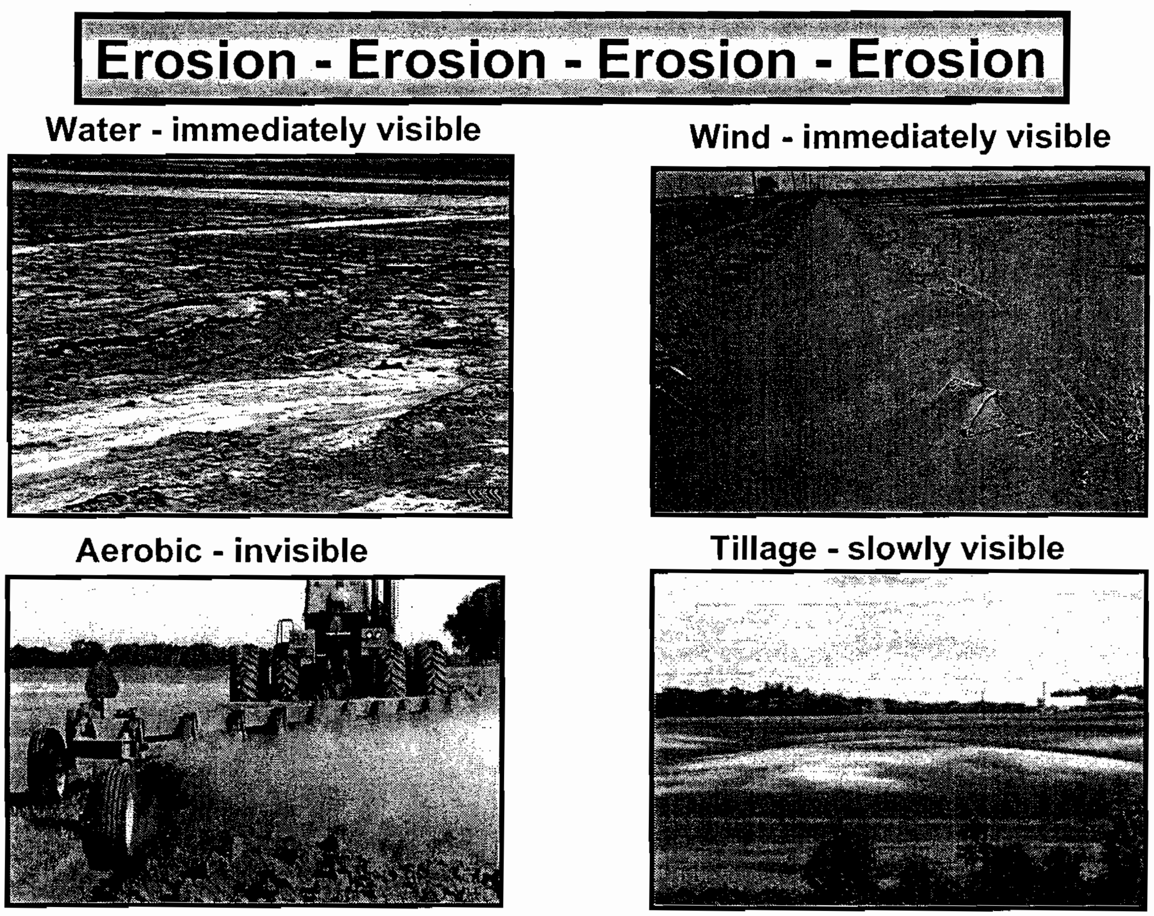

Figure 2. Four types of erosion that include water, wind, aerobic (tillage-induced oxidation), and tillage erosion all related to intensive tillage in our agricultural production systems.

Conservation Practices

Agricultural ecosystems are regularly disturbed systems. The physical disturbance of the above- and below-ground species by tillage, as well as grain and biomass removal, fertilizer nutrient input and the addition of pesticides and herbicides all contribute to the ecosystem disturbance. Fields are managed to maximize production of plant biomass and grain yields that are regularly harvested. The crop biomass removed from the system annually constitutes a removal or a mining of C and nutrients from the agro-ecosystem. After repeated annual cycles of removing grain and biomass from the system, the soil becomes poor in nutrients and organic matter (OM). The continued long-term removal of grain and crop biomass represents a net exporting of C from the crop system primarily used for animal or human nutrition. Much of this C loss comes from the soil. We must not continue to "mine" our production systems. Thus to maintain sustainability of the soil resource, we must think about soil C management and make efforts to maximize C input and minimize C loss.

Soil conservation practices not only reduce soil erosion but also increase the OM content of soils. Principal conservation strategies, which sequester C, include converting marginal lands to compatible land use systems, restoring degraded soils, and adopting best management practices. For example, removing agriculturally marginal land from annual crop production and adopting an ecologically compatible land use, such as livestock grazing and/or wildlife habitat, can lead to increases in total biomass production and an increase in C content in the soil. Best management practices (BMPs) that have been proven to sequester soil C are crop residue management, conservation tillage practices like direct seeding systems, no till, conservation tillage, mulching, strip cropping, diverse crop rotations, cover crops, grassed waterways, elimination of summer fallow; perennial forage crops for hay or pasture; application of organic materials and manures; soil fertility optimization through improved fertilizer placement and site-specific management. In addition to promoting C sequestration, BMPs can also improve crop yields by reducing soil erosion and degradation while improving water quality by reducing silt and agricultural runoff into nearby waterways. Agricultural activities related to C sequestration considered conservation practices include conserving fuel, managing nutrients and irrigation efficiently, using aerobic systems such as composting, producing dedicated biofuel crops, incorporating new crops, installing vegetative conservation buffers and restoring and protecting wetlands.

Soil Organic Matter and Carbon Properties

There are many different names, classes or types of OM in the soil system. Two broad C classifications are organic and inorganic. The inorganic C includes the free calcium carbonates and other inorganic sources. Soil organic matter (SOM) generally refers to natural C-containing organic materials living or dead, but excluding charcoal. Soil organic matter includes living organisms such as bacteria, fungi, nematodes, protozoa, earthworms, arthropods, and living roots. Organic C (OC) is the C content that is commonly used to characterize the amount of OM in soils (OM = 1.724 * %OC). Phytomass is another name for the above ground biomass of plant origin, usually living, but may also include dead plants. Litter comprises the dead plant and animal debris on the soil surface. Dead plant material, OM, detritus, and surface residue all refer to plant, animal, or other organic substances that have recently been added to the soil and have only begun to show signs of decay. Active fraction OM can be used as food by microorganisms and changes more quickly than total OM in response to management changes. Labile OM is also easily decomposed. Root exudates include soluble sugars, amino acids and other compounds secreted by roots. Microbial biomass is the living population of soil microorganisms. Macroorganic matter is organic fragments from any source which are > 250μm. Particulate organic matter or Light fraction OM have precise size and weight definitions and are thought to represent the active fraction of OM which is more difficult to define. Lignin is a hard-to-degrade compound that is part of the fibers of older plants degraded by fungi. Recalcitrant OM includes humus or lignin-containing material that few soil organisms can decompose. Humus is organic material remaining in soils after removal of macroorganic matter. Humic acids, fulvic acids, and humin are dark-colored amorphous materials considered generally insoluble under natural conditions that can be extracted from the soil by a variety of strong reagents.

Our soil systems contain many different forms of C. Organic C is the most important to us because it is the key chemical for energy and building blocks of all OM produced in the biological C cycle and is linked to all measures of soil quality. These C forms given in figure 3 range from crop residue and rhizo-deposition to wood chips and biodegradable garbage and everything in between. The OM must be amenable to attack by microbes and fungi and ultimately decompose into unrecognizable organic material accompanied by CO_2 emissions from microbial respiration. The common link of all these materials is their basic composition that includes a significant portion of the material that points to C.

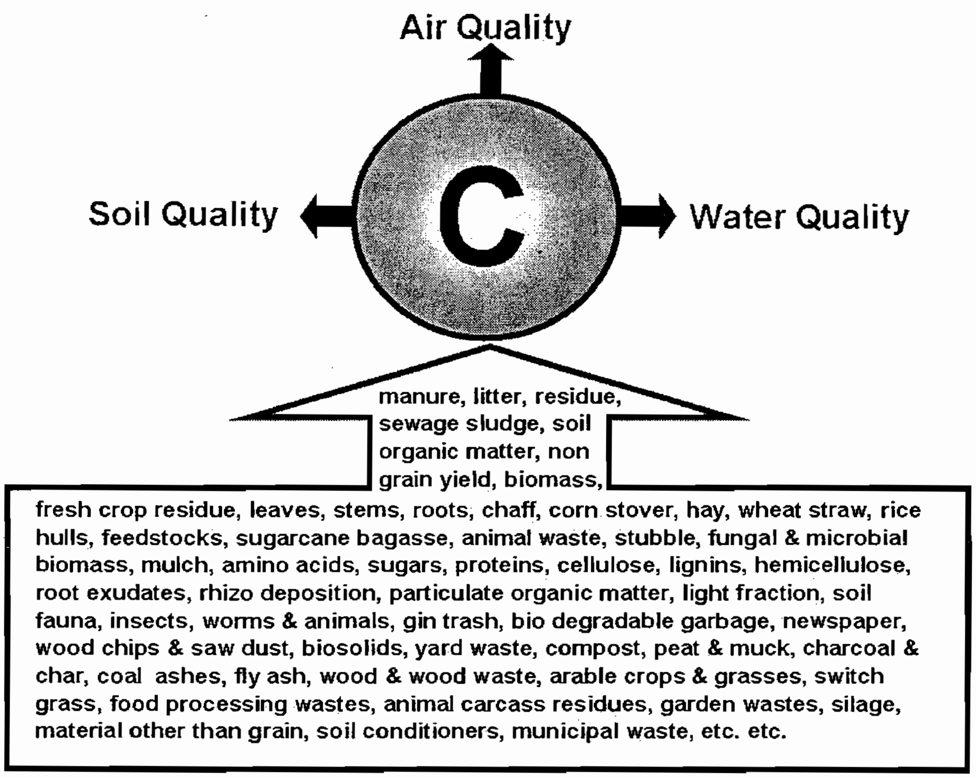

Figure 3. Various types and forms of organic matter that all point to soil C and associated environmental quality components.

Carbon in Conservation: The Biological C Cycle

Agriculture manages a large portion of the landscape to capture C through the process of photosynthesis that provides food, fiber and biofuels. Carbon dioxide (CO_2) uptake through photosynthesis converts solar energy to a useful form of C, or forms of energy that is the start of the grand biological C cycle. The C cycle is driven by solar radiation that allows photosynthesis and evapotranspiration of water required for biomass generation. The sun drives the atmosphere into patterns of everyday wind and weather and is the ultimate source of all energy on earth. Crop residue and plant roots and their exudates are the primary source of C in our agricultural ecosystems. Approximately 50% of the C in crop residues is recycled back to the atmosphere within the next year as part of the biological C cycle. The current interest in using agricultural residues for biofuels presents some challenges depicted in figure 4. We must maintain the delicate balance between the C required for good soil conservation and biomass removal for biofuel production.

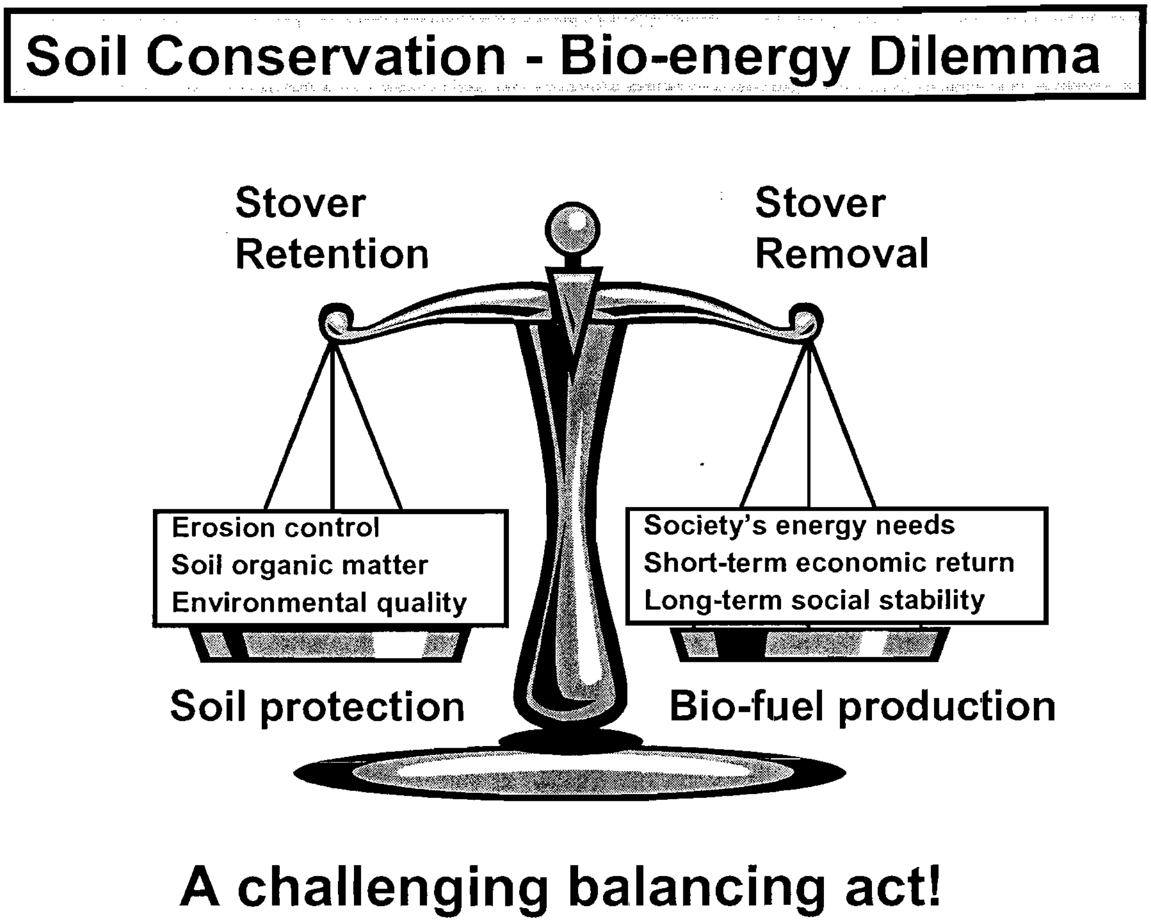

Figure 4. Maintaining the delicate balance of stover retention for soil conservation and stover removal for biofuel production.

The C cycle is central to the Earth's system, being tightly coupled with climate, the water cycle, nutrient cycles and the production of biomass by photosynthesis on land and in the oceans. A proper understanding of the global C cycle is critical for understanding the environmental history of our planet and its human inhabitants, and for predicting and guiding their joint future. Carbon can be found in many different forms and locations. The "biological C" cycle is of the utmost importance in conservation agriculture and is differentiated from the "fossil C" cycle as illustrated in figure 5. The process of fossil C sequestration requires the capture and storage of C content of fossil fuels prior to its release to the atmosphere. Biological C sequestration also requires removal of C from the atmosphere by plants. Fossil fuels (fossil C) are very old geologically, as much as two hundred million years. One example of biological C cycling is the agricultural production of biomass for fuel with the potential to reduce net CO_2 emissions to the atmosphere. Enhanced C management in conservation agriculture may make it possible to take CO_2 released from the fossil C cycle and transfer it to the biological C cycle to enhance food, fiber and bio-fuel production as well as enhancing environmental quality. Carbon is the "graphite" that lubricates and the "fuel of the soil" that energizes our ecosystems. The C lubricates all processes and properties so that the ecosystem runs smoothly. By properly managing the C cycle in our agricultural ecosystems, we can have less erosion, less pollution, clean water, fresh air, healthy soil, natural fertility, higher productivity, beautiful landscapes, and sustainability.

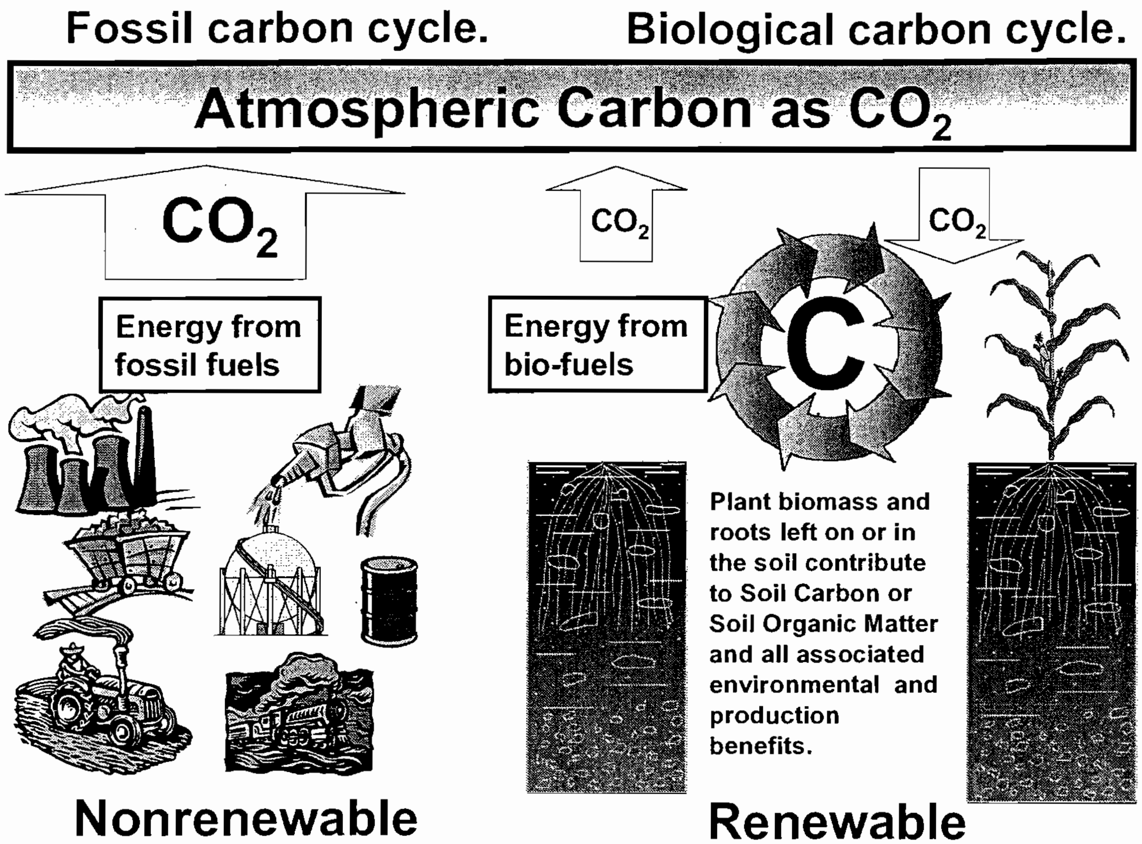

Figure 5. The biological Carbon cycle is renewable and sustainable when compared to the fossil Carbon cycle.

Summary

True soil conservation is C management. The time has come for a shift in our conservation concepts and programs to get away from the stale approach of managing for only erosion control and move to managing for soil C. True soil conservation must expand beyond the traditional understanding of soil erosion. We need to move to the next level of conservation by shifting our focus to managing for both erosion control and soil C for soil quality. As we clearly understand the role of C in true conservation, we must be better managers of soil C. While soil erosion continues to be a major problem, we must expand our thinking to address related soil quality issues, which translates to soil C. Carbon management is required to address a complex list of issues including soil, water quality, biofuel, and climate change. The soil is the fundamental foundation of our economy and our existence. The current concern about possible global change and management options elevates the importance of C management and conservation. There is a question whether C management should focus on C sequestration or on C cycling. More research is needed to address this issue and it is likely that some practical compromise will be required. As in many "natural processes," we must balance sequestration and cycling for enhanced physical, chemical and biological properties and processes. Today, we must place more emphasis on all natural resources and additional emphasis on C as a key component in maintaining ecosystem stability. Yes, true “C”onservation starts with “C” management.