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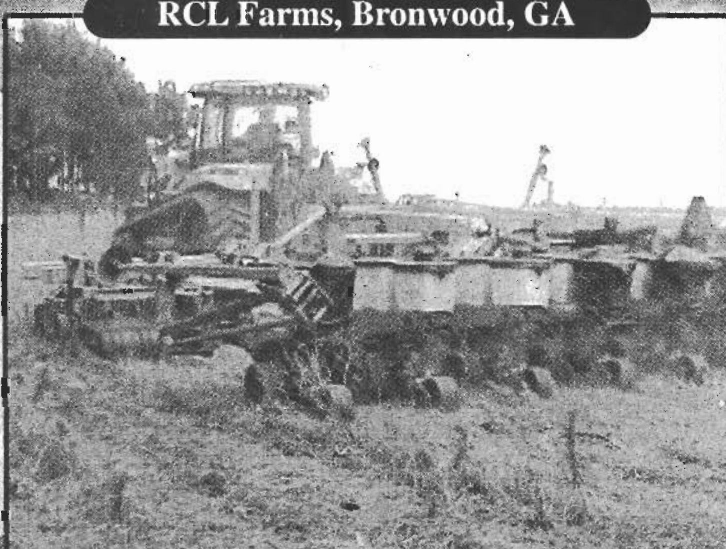

RCL Farms, Bronwood, GA

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Publisher
Clifton Dixon
October 2003

Co-Editors
Wanda Wade
Clifton Dixon

Soil Organic Matter: Benefits of Direct Seeding to Productivity and Environment

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Summary

Agricultural management of soil organic matter may be one of the most cost effective ways to slow processes of global warming. Direct seeding aims to conserve, improve and make more efficient use of natural resources through integrated management of available soil, water and biological resources. Numerous environmental benefits may result from agricultural activities that sequester soil carbon (C) and contribute to environmental security. As part of no-regret strategies, practices that sequester soil C help reduce soil erosion and improve water quality and are consistent with more sustainable and less chemically dependent agriculture. While we learn more about soil C storage and its central role in direct environmental benefits, we must understand the secondary environmental benefits and what they mean to production agriculture. Increasing soil C storage through direct seeding can increase infiltration, increase fertility and nutrient cycling, decrease wind and water erosion, minimize compaction, enhance water quality, decrease C emissions, impede pesticide movement and generally enhance environmental quality. The sum of each individual benefit adds to a total package with major significance on a global scale. Incorporating C storage in conservation planning demonstrates concern for our global resources and presents a positive role for soil C that will have a major impact on our future quality of life.

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

Introduction

Intensification of agricultural production has been an important factor influencing greenhouse gas emission. Agricultural activities contribute to carbon dioxide (CO2) emissions to the atmosphere through the combustion of fossil fuel, soil organic matter (SOM) decomposition, and biomass burning. Improved conservation agricultural practices have great potential to increase soil carbon (C) sequestration and decrease net emissions of CO2 and other greenhouse gases that contribute to global environmental security.

World soils are an important pool of active C and play a major role in the global C cycle and have contributed to changes in the concentration of greenhouse gases in the atmosphere. Agriculture is believed to cause some environmental problems, especially related to water contamination, soil erosion, and greenhouse effect. The soil contains two to three times as much C as the atmosphere. In the last 120 years, intensive agriculture has caused a C loss between 30 and 50 %. By minimizing the increase in ambient CO2 concentration through soil C management, we minimize the production of greenhouse gases and minimize potential for climate change. Recent results suggest scientific agriculture can also lessen environmental problems and mitigate the greenhouse effect. In fact, agricultural practices have the potential to store more C in the soil than farming emits through land use change and fossil fuel combustion.

Soil quality is the fundamental foundation of environmental quality. Soil quality is largely governed by SOM content, which is dynamic and responds effectively to changes in soil management, primarily tillage and C input. This review will primarily address soil C and its associated environmental benefits. Agriculture has an opportunity to offset some CO2 emissions and will be a small, but significant player in sequestering C.

Key role of soil organic matter

Soil organic C represents a key indicator for soil quality, both for agricultural functions (production and economy) and for environmental functions (C sequestration and air quality). Soil organic matter is the main determinant of biological activity because it is the primary energy source. The amount, diversity and activity of soil fauna and microorganisms are directly related to SOM content and quality. Organic matter and the biological activity that it generates, have a major influence on the physical and chemical properties of the soils. Soil aggregation and stability of soil structure increases with increasing organic C. These factors in turn increase the infiltration rate and available water holding capacity of the soil as well as resistance against erosion by wind and water. Soil organic matter also improves the dynamics and bio-availability of main plant nutrient elements.

Soils contain relatively small amounts of C that could be considered analogous to a catalyst for biological activity where a small amount has a big impact. Farmers are the primary soil managers who each have a tremendous responsibility to maintain SOM for environmental benefit of the global population. Thus, farmers who use conservation agriculture or direct seeding techniques are providing ecosystem services and helping to maintain environmental quality for all of society. Quality food production and economic and environmentally-friendly management practices that are socially acceptable will lead to sustainable production and be mutually beneficial to farmers and all of society. It is important, therefore, that C loss from the soil system through historical land use of farming practices be restored to its natural potential using direct seeding and conservation tillage methods for sustainable production.

Sources and sinks in agricultural systems

Agricultural systems contribute to C emissions through several mechanisms including direct use of fossil fuels in farm operations, indirect use of energy inputs for manufacturing chemicals (typically fertilizers), irrigation and grain drying and through intensive tillage of soils resulting in the loss of SOM. With conservation agriculture techniques, soils can accumulate C to offset other C losses. Thus, the soil can be converted from a "source" of C to a "sink" for C with improved soil and crop management.

Preliminary assessments indicate that soil C sequestration can be a tool to offset C emissions from burning fossil fuels. We in agriculture play a significant role because of the large amount of soil C in the C cycle within agricultural production systems. The limited use of crop rotations combined with intensive tillage decreases soil quality and soil organic matter.

Any operation that removes or incorporates crop residue contributes to the decline of soil C through increased biological oxidation. The drive to maximize profit in food and fiber production has created environmental problems that have slowly crept up on conventional agriculture and now requires new knowledge, research and innovation to overcome these concerns.

Environmental benefits of soil carbon

The main direct benefit of conservation agriculture or direct seeding is the immediate impact on SOM and soil C interactions. Soil organic matter is so valuable for what it does, it can be referred to as "black gold" because of its vital role in physical, chemical and biological properties and processes within the soil system. Agricultural policies are needed to encourage farmers to improve soil quality by storing C that will also lead to enhanced air quality, water quality and increased productivity as well as to help mitigate the greenhouse effect. Soil C is one of our most valuable resources and may serve as a "second crop" if global C trading systems become a reality. While technical discussions related to C trading are continuing, there are several other secondary benefits of soil C impacting environmental quality that should be considered to maintain a balance between economic and environmental factors.

Soil C is so important that it can be compared to the central hub of a wagon wheel as shown in Fig 1. The wheel represents a circle, which is a symbol of strength, unity and progress. The "spokes" of this wagon wheel represent incremental links to soil C that lead to the environmental improvement that supports total soil resource sustainability. Many spokes make a stronger wheel. Each of the secondary benefits that emanate from soil C contributes to environmental enhancement through improved soil C management. Some of the "spokes" of the environmental sustainability wheel are described in following paragraphs.

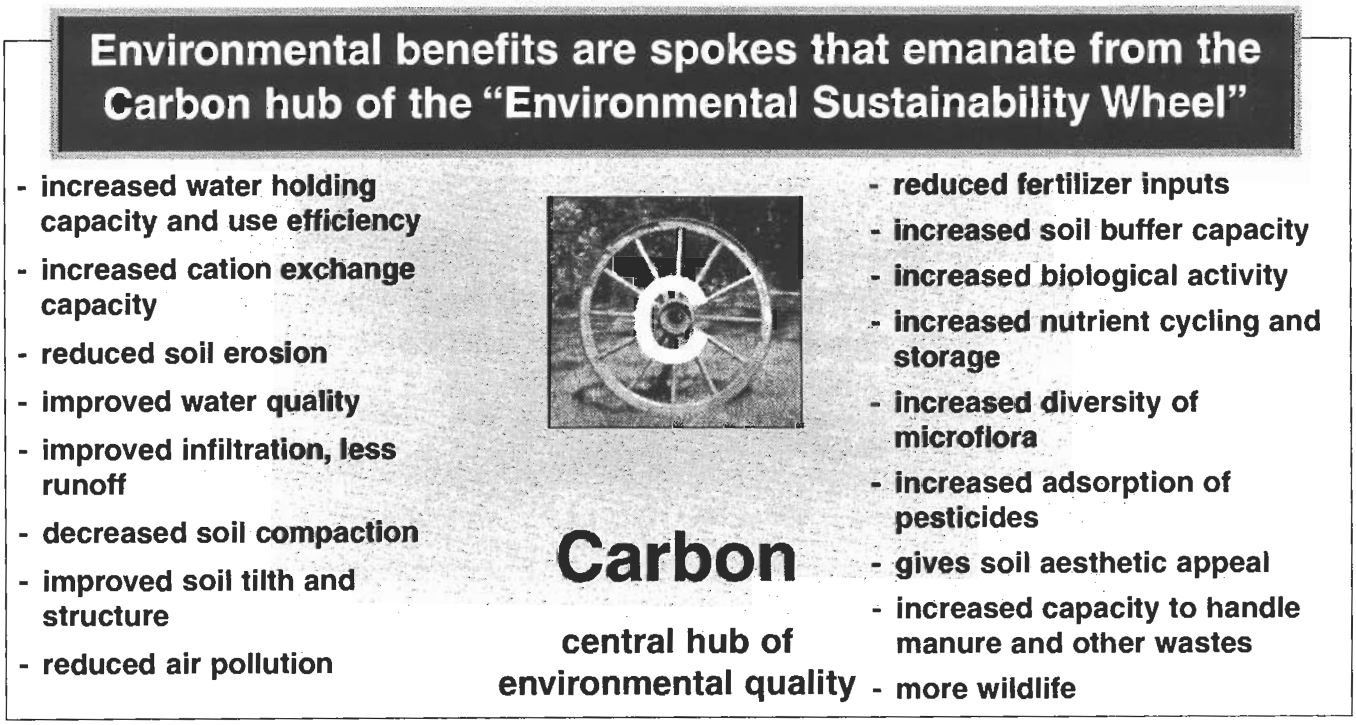

Fig 1. Environmental sustainability wheel with benefits emanating from the soil C hub.

Increased SOM has a tremendous effect on soil water management because it increases infiltration and the water holding capacity. The primary role of SOM in reducing soil erodibility is by stabilizing the surface aggregates through reduced crust formation and surface sealing, which increases infiltration. Enhanced soil water-holding capacity is a result of increased SOM that more readily absorbs water and releases it slowly over the season to minimize the impacts of short-term drought. In fact, certain types of SOM can hold up to 20 times its weight in water. For each one % increase in SOM, the available water holding capacity in the soil increased by 3.7 % of the soil volume. The extra SOM prevents drying and improves water retention properties of sandy soils. In all texture groups, as SOM content increased from 0.5 to 3 %, available water capacity of the soil more than doubled. Other factors being equal, soils containing more organic matter can retain more water from each rainfall event and make more of it available to plants. This result plus the increased infiltration with higher organic matter and the decreased evaporation with crop residues on the soil surface all contribute to improve water use efficiency.

Ion adsorption or exchange is one of the most significant nutrient cycling functions of soils. Cation exchange capacity (CEC) is the amount of exchange sites that can absorb and release nutrient cations. Soil organic matter can increase CEC of the soil from 20 to 70 % over that of the clay minerals and metal oxides present. In fact, the contribution of the organic matter to the cation exchange capacity exceeded that of the kaolinite clay mineral in the surface 2 in. A strong linear relationship was shown between organic C and CEC of an experimental soil. The CEC increased four-fold with an organic C increase from 1 to 4 %. The toxicity of other elements can be inhibited by SOM which has the ability to adsorb soluble chemicals. The adsorption by clay minerals and SOM is an important means by which plant nutrients are retained in crop rooting zones.

Soils relatively high in C, particularly with crop residues on the soil surface, are very effective in increasing SOM and in reducing soil erosion loss. Reducing or eliminating runoff that carries sediment from fields to rivers and streams will enhance environmental quality. Under these situations, the crop residue acts as tiny dams that slow down the water runoff from the field allowing the water more time to soak into the soil. Worm channels, macropores and plant root holes left intact increase infiltration. Water infiltration is two to ten times faster in soils with earthworms than in soils without earthworms. Soil organic matter contributes to soil particle aggregation that makes it easier for the water to move through the soil and enables the plants to use less energy to establish to root systems. Intensive tillage breaks up soil aggregates and results in a dense soil making it more difficult for the plants to get nutrients and water required for their growth and production.

The reduction in soil erosion leads to enhanced surface and ground water quality, another secondary benefit of higher SOM. Crop residues on the surface help hold soil particles in place and keep associated nutrients and pesticides on the field. The surface layer of organic matter minimizes herbicide runoff, and with conservation tillage, herbicide leaching can be reduced as much as half. The enhancements of surface and ground water quality are accrued through the use of conservation tillage and by increasing SOM. Increasing SOM and maintaining crop residues on the surface reduces wind erosion. Depending on the amount of crop residues left on the soil surface, soil erosion can be reduced to nearly nothing as compared to the unprotected, intensively tilled field.

Different mechanisms where soil "compactibility" can be decreased by increased SOM content are: 1) improved internal and external binding of soil aggregates; 2) increased soil elasticity and rebounding capabilities; 3) dilution effect of reduced bulk density due to mixing organic residues with the soil matrix; 4) temporary or permanent existence of root networks; 5) localized change electrical charge of soil particles surfaces, and 6) change in soil internal friction. While most soil compaction occurs during the first vehicle trip over the tilled field, reduced weight and horsepower requirements associated with forms of conservation tillage can also help minimize compaction. Additional field traffic required by intensive tillage compounds the problem by breaking down soil structure. The combined physical and biological benefits of SOM can minimize the affect of traffic compaction and result in improved soil tilth.

Maintenance of SOM contributes to the formation and stabilization of soil structure. Another spoke in the wagon wheel of environmental quality is improved soil tilth, structure and aggregate stability that enhances the gas exchange properties and aeration required for nutrient cycling. Critical management of soil airflow with improved soil tilth and structure is required for optimum plant function and nutrient cycling. It is the combination of many little factors rather than one single factor that results in comprehensive environmental benefits from SOM management. The many attributes suggest new concepts on how we should manage the soil for the long-term aggregate stability and sustainability.

A secondary benefit of less tillage and increasing SOM is reduced air pollution. CO2 is the final decomposition product of SOM and is released to the atmosphere. Research has shown that intensive tillage, particularly the moldboard plow, releases large amounts of CO2 as a result of physical release and enhanced biological oxidation. With conservation tillage, crop residues are left more naturally on the surface to protect the soil and control the conversion of plant C to SOM and humus. Intensive tillage releases soil C to the atmosphere as CO2 where it can combine with other gases to contribute to the greenhouse effect. Thus a combination of the economic benefits of conservation tillage through reduced labor requirements, time savings, reduced machinery costs and fuel savings, combined with the environmental benefits listed above has universal appeal. Indirect measures of social benefits as society enjoys a higher quality of life from environmental quality enhancement will be difficult to quantify. Conservation agriculture, using direct seeding techniques, can benefit society and can be viewed as both "feeding and greening the world" for global sustainability.

Carbon sequestration policies and perspectives

Carbon sequestration through continuous conservation agriculture is only a short-term solution to the problem of global warming. The amount of C that can be stored in the soil using no till techniques will plateau in 25 to 50 years. The time period depends on the specific geographic site, soil and climate parameters, and cropping practices that are followed. At some point, a new equilibrium will be reached where there is no further gain in soil C; however, the environmental benefits will continue. In the long-term, reducing CO2 emissions from the burning of fossil fuels by developing alternate energy sources is the only solution. Soil C sequestration and potential associated C credit trading will allow major CO2 emitters time to reduce their emissions, while developing economical long-term solutions.

Agricultural policy should play a prominent role in agro-environmental instruments to support a sustainable development of rural areas and respond to societies increasing demand for environmental services. Environmental protection and nature conservation require enhanced management skills that create extra work and cost for the farmers, but in no other sector can so much be achieved for the environment with so little input. We must no longer take for granted the contribution made to society by farmers through environmental measures but must compensate them appropriately through stewardship payments. Farmers using conservation techniques stand to gain from protecting the environment because it is in their fundamental economic interest to conserve natural resources for the future. It is in all our economic interests to have healthy and sustainable ecosystems to enhance our quality of life. The true economic benefits can only be determined when we assign monetary values to externalities of environmental quality.

Trade in C credits has potential to make conservation agriculture more profitable and enhance the environment at the same time. The potential for C credits has attracted considerable attention of farmers and likely buyers of the C credits. Rules for trading in C credits are not yet agreed upon but international dialogue is underway to develop a workable system and rules for trading. The number of organizations working on developing a C trading system in appendix table 1 suggests that some type of international mechanism will evolve and that C credit trading will become a reality. Potential suppliers and buyers of C credits are urged to proceed with caution because many of the issues central to C credit markets and trade are yet to be clarified. We must convince policy makers, environmentalists and industrialists that soil C sequestration is an additional important benefit of adopting improved and recommended conservation agricultural production systems. This option stands on its own, regardless of the threat of global climate change from fossil fuels.

Conservation agricultural practices can help mitigate global warming by reducing C emissions from agricultural land and by sequestering C in the soil through regulatory, market incentive, and voluntary or educational means. Public policy can encourage adoption of these practices. For the present, there is a degree of uncertainty for investors and potential investors in forest related C sinks over the specific rules that will apply to implementation of the sinks provisions of the Kyoto Protocol. Investors and potential investors in C sinks need to be aware that there is uncertainty at the international level. Administration and transaction costs could play a key role in determining the success of any C credit trading system. Cost of these areas are expected to be minimized through improved techniques and services for measuring and reporting sequestered C, private sector consultants, economies of scale, and the emergence of market mechanisms and strategies such as C pooling or aggregating. There are risks involved in selling C credits in advance of any formalized international trading system and those participating in early trading need to clarify responsibilities and obligations. However, care should be taken in the design of these policies to ensure their success and to avoid unintended adverse economic and environmental consequences and to provide maximum social benefit.

Conservation agriculture with enhanced soil C management is a win-win strategy. Agriculture wins with improved food and fiber production systems and sustainability. Society wins because of the enhanced environmental quality. The environment wins as improvements in soil, air and water quality are all enhanced with increased amounts of soil C. The win-win scenario will increase productivity, improve soil quality, and mitigate the greenhouse effect with major impact on our future quality of life.

Appendix Table 1.

Partial listing of carbon credit trading information programs and web site addresses as of 1 May 2003.

Australian National University Forestry
http://www.farmwide.com.au/features/report12.pdf
Nebraska Carbon Sequestration Advisory Committee
http://www.carbon.unl.edu/carbstor.htm
Chicago Climate Exchange.
www.chicagoclimatex.com/html/ETIndia102502.htm
http://www.chicagoclimatex.com/
Econergy International Corporation
http://www.eic-co.com/Whois.htm
The Australian Greenhouse Office
http://www.greenhouse.gov.au/emissionstrading/factsheets/qanda.html
Effluent Trading: Tradable Pollution Permits for Improved Environmental Quality
http://ageco.tamu.edu/faculty/woodward/ET.htm
International Emissions Trading Association (IETA).
http://www.ieta.org/
Cantor Fitzgerald's Environmental Brokerage Services
http://www.co2e.com/common/faq.asp?intPageElementID=34307&intCategoryID=29
Environmental Financial Products, LLC.
http://www.envifi.com/
The Carbon Trader
http://www.thecarbontrader.com/
Point Carbon Price Forecasting
http://www.pointcarbon.com/
Natsource - Consultative Services
http://www.natsource.com/
The Prototype Carbon Fund
http://www.prototypecarbonfund.org/router.cfm?Page=Home
Trexler and Associates, Inc. climate services
http://www.climateservices.com/
Climate Change Knowledge Network News
http://www.cckn.net/climate_news.asp
International Carbon Bank and Exchange
http://www.carbonexchange.com
The Carbon Credit Portal
http://www.carboncredit.org
World Bank Research
http://www.worldbank.org/research/projects/global.htm
eCarbontrade
http://www.ecarbontrade.com
The Carbon Protocol
http://www.thecarbonprotocol.com
The Carbon Fund
http://www.thecarbonfund.org
Clean Air Market Programs: Allowance Data
http://www.epa.gov/airmarkets/trading
Agriculture's Role Discussed in Carbon Trading
http://www.fb.com:80/news/fbn/html/agriculture_s.html