No-Till On The Plains 2001 Speakers - D.C. Reicosky

No-Till and Carbon Sequestration

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Introduction

Agriculture, the major industry for food and fiber production, is known to cause both emission and storage of greenhouse gases. Intensification of agricultural production is an important factor influencing greenhouse gas emission and plays a key role in the harmony of man and nature. More than 97% of the world's food supply is produced on land that emits greenhouse gases when intensively tilled and fertilized or grazed to support animal production (Lal et al., 1998). While agriculture is generally thought of as a minor source of greenhouse gases, increasing world population dictates the challenge of increased agricultural production without increasing the risks of greenhouse gas emissions and possible environmental consequences. As we enter the third millennium, this review will focus on the role of agriculture as a means of sequestering or storing soil carbon (C) to minimize possible environmental consequences associated with intensive agriculture and will address elevated soil C loss as caused by intensive tillage. Thus producers, scientists and planners are faced with the challenge to increase agricultural production without accentuating the risks of greenhouse gas emissions and their impact on environmental quality. One practice that combines many of the above factors is no-till (direct seeding) with limited soil disturbance during the planting operation that provides a multitude of environmental benefits.

Soil organic matter or C is the critical component associated with agro-system productivity. Soil carbon provides an important link between sustainability and productivity within our agricultural production systems. Long-term data records indicate that intensive cultivation and tillage usually causes a decrease in soil organic C content. No till has been proposed as an alternative to conventional cropping systems for reducing soil degradation and minimizing soil erosion and generally leads to a soil C increase in the top 5-10 cm of the soil profile relative to moldboard plowed soils.

Recent studies involving a dynamic chamber, various tillage methods and associated incorporation of residue in the field indicated major C losses immediately following tillage (Reicosky and Lindstrom, 1993). The short-term impact of moldboard plow and various tillage methods on CO_2 loss from the soil was measured using a portable dynamic chamber designed to measure canopy photosynthesis and mounted on the front end of a 4-wheel drive forklift for portability. Reicosky and Lindstrom (1993) found that the moldboard plow had the roughest soil surface, the highest initial CO_2 flux and maintained the highest flux throughout the 19-day study. High initial CO_2 fluxes were more related to the depth of soil disturbance that resulted in a rougher surface and larger voids than to residue incorporation. Lower CO_2 fluxes were caused by tillage associated with low soil disturbance and small voids with no-till having the least amount of CO_2 loss during 19 days. Reicosky and Lindstrom (1993) concluded that intensive tillage methods, especially moldboard plowing to 10 in. deep, affected this initial soil flux differently and suggest improved soil management techniques can minimize agricultural impact on global CO_2 increase. Strip tillage with less soil disturbance resulted in less CO_2 loss and no-till the least (Reicosky, 1998).

The literature holds considerable evidence that intensive tillage decreases soil C and supports increased adoption of new and improved forms of conservation tillage to preserve or increase storage of soil organic matter (Lal et al., 1998). Based on the soil C losses with intensive agriculture, reversing the decreasing soil C trend with less tillage intensity should be beneficial to sustainable agriculture and the global population by gaining better control of the global C balance. Better control of the carbon balance will lead to better harmony between man and nature. The environmental and economic benefits of conservation tillage and no-till demand their consideration in the development of improved soil carbon storage practices for sustainable production. Thus, the objective of this review was to increase awareness of the importance of soil carbon storage. The data and results will be related to environmental benefits of soil C storage for global sustainability.

Environmental Benefits for Global Sustainability from Storing Soil Carbon

As we enter the new millennium with optimism, agriculture can enhance the harmony between man and nature. Agriculture has an opportunity to offset some CO_2 emissions and will be a small, but significant player in storing or sequestering carbon (C). Preliminary assessments indicate that soil C sequestration can be a tool in offsetting C emissions from burning fossil fuels. All potentially important technical options need to be explored. 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 the 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 that now requires new knowledge, research and innovation to overcome these concerns for sustainable production.

The main benefit of no-till or conservation tillage is the immediate impact on soil organic matter and soil C interactions. Soil organic matter is so valuable for what it does in the soil, 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 mitigating the greenhouse effect. Soil C is one of our most valuable resources and may serve as a "second crop" if global C trading systems becomes 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. In agricultural production systems, many decisions are made based on farmer experience and economic considerations. However, the recent emphasis on environmental concerns requires a balance between economic and environmental factors that have caused soil organic matter management decisions to rise to a high-level priority. Thus, the recent interest in soil C storage or sequestration.

Carbon sequestration means to "capture and secure or store", in this case soil C. Agriculture can be converted from a source of CO_2 with intensive soil tillage operations to a sink of CO_2 with no-till techniques which help store and sequester the C in a form that will minimize the impact on the environment. Preliminary assessments indicate that soil C storage can be a tool in offsetting C emissions from burning of fossil fuels (Lal et al., 1998). The main goal is to enhance C fixation through photosynthesis and to reduce soil C emissions by securing and storing C that might otherwise be lost to the atmosphere. 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 percent. By minimizing the increase in CO_2 concentration through soil C management, we minimize the production of greenhouse gases and minimize potential for climate change. Agriculture, in general, has an opportunity to offset some CO_2 emissions and make a small but significant change in the total C cycle. All potentially important technical options need to be explored.

Soils contain relatively small amounts of C that could be considered analogous to a catalyst or to the tip of the iceberg where a small amount visible has a big impact. Soil C performs many important beneficial functions with respect to environmental enhancement. Farmers are the primary soil managers who each have a tremendous responsibility to maintain soil organic matter for environmental benefit of the global population. Thus, farmers who use no-till techniques or conservation tillage techniques are 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. 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. Enhanced soil C storage and management also helps the environment win as improvements in soil, air and water quality are all enhanced with increased amounts of soil C within the soil. The win-win scenario will increase productivity, improve soil quality, and mitigate the greenhouse effect. 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 no-till and conservation tillage methods for sustainable production.

Soil C can be considered the central hub of an environmental sustainability wheel that supports secondary environmental benefits represented by the spokes of the wheel. The spokes of this wagon wheel are the incremental links to soil C that lead to the environmental improvement that supports total soil resource sustainability. Each of the several items can be considered secondary benefits that emanate from soil C for environmental enhancement through improved soil C management. Important spokes that emanate from C as the hub of this environmental wheel are the spokes that increase water holding capacity and water use efficiency. Increased soil organic matter is known to increase the water holding capacity along with increasing infiltration so that it has a tremendous effect on soil water management. Soils relatively high in C, particularly with crop residues on the soil surface, are very effective in increasing soil organic matter and in reducing soil erosion loss. 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. Infiltration is increased by worm channels, macropores and plant root holes that are left intact. 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. Enhanced environmental quality is achieved by reducing or eliminating runoff that carries sediment from fields to rivers and streams.

The reduction in soil erosion leads to enhanced surface and ground water quality, another secondary benefit of higher soil organic matter. 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 runoff 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 the soil organic matter. Increasing the soil organic matter 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.

Another spoke in the wagon wheel of environmental quality is improved soil tilth and structure that enhances the gas exchange properties and aeration required for nutrient cycling. This concept of what soil C can do is so critical in environmental issues and needs to be understood by everyone, especially farmers. It is the combination of many little factors rather than one single factor that results in comprehensive environmental benefits from soil organic matter management. The many attributes suggest new concepts on how we should manage the soil for the long-term sustainability.

Another benefit not often considered is the increase in soil water-holding capacity. The enhanced soil water-holding capacity is a result of increased soil organic matter that more readily absorbs water and releases it more slowly over the season to minimize the impacts of short-term drought. Leaving the crop residue on the surface also reduces water evaporation in the top few inches of the soil and thus, conserves water for the dry periods. Other forms of conservation tillage can make additional water available during the growing season that can make or break the final yield.

Soil organic matter can be influential in decreasing soil compaction. While most compaction occurs during the first trip over the field, reduced weight and horsepower requirements associated with forms of conservation tillage can 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 soil organic matter can minimize the affect of traffic compaction and result in improved soil tilth.

Another secondary benefit of less tillage and increasing soil organic matter is reduced air of pollution. CO_2 is the final decomposition product of soil organic matter and is released to the atmosphere. Research has shown that intensive tillage, particularly the moldboard plow, releases large amounts of CO_2 as a result of physical release and enhanced biological oxidation. With conservation tillage, crop residues are left more naturally on the surface to keep plant C on the soil surface for use in slow conversion to soil organic matter. Intensive tillage releases soil C to the atmosphere as CO_2 where it can combine with other gases to contribute to the greenhouse effect. These results illustrate management's options to reduce agriculture's contribution to the greenhouse effect and point to needed future research to minimize the impact on environmental quality.

Conservation farming saves time, saves money, and can be useful in saving the planet. Eco-efficient farming is economically competitive and environmentally friendly that maintains the sustainability of food and fiber production. This requires a certain level of environmental consciousness and a normal part of doing business in modern day agriculture. We must reduce pollution and use our resources in line with the earth's caring capacity for sustainable production of food and fiber. The responsibility lies on the shoulders of the farmer to maintain a delicate balance between the economic implications of farming practices and the environmental consequences of using the wrong practices. This responsibility entails producing food and fiber to meet the increasing population and still maintain the environment for a high quality of life. Soil carbon storage is a big contributor to environmental quality.

Agriculture is believed to be the cause of some of the environmental problems, especially those related to water contamination from sedimentation and the greenhouse effect with tillage-induced CO_2 losses. Improved management techniques have shown that scientific agriculture can also be a solution to these environmental issues in general and specifically to mitigating the greenhouse effect. Improved agricultural practices such as no-till or conservation tillage can have the potential to sequester more C in the soil than farming emits through land use and fossil fuel combustion. Thus a combination of the economic benefits of enhanced soil management through reduced labor requirements, time savings, reduced machinery and fuel savings with no-till, 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. Agriculture, using no-till techniques, can be of utmost benefit to society and can be viewed as both "feeding and greening the world" for global sustainability.

In summary, while we learn more about soil C storage and its central role in direct environmental benefits, we must understand the secondary environmental benefits of no-till and what they mean to sustainable production agriculture. Understanding these environmental benefits and getting the conservation practices implemented on the land will hasten the development of harmony between man and nature. Increasing soil C storage can increase infiltration, increase fertility, decrease wind and water erosion, minimize compaction, enhance water quality, decrease C emissions, impede pesticide movement and enhance environmental quality. Accepting the challenges of the third millennium by incorporating C storage in conservation planning demonstrates concern for our global resources. This concern presents a positive role for agriculture and conservation that will have a major impact on global sustainability and our future quality of life.

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