Conservation agriculture and carbon management

Soil carbon management is critical to our economy and our existence for maintaining sustainable production and ecosystem services for our quality of life.

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The increasing pressure to provide food security, enhance environmental quality and address societal problems creates challenges for agriculture and requires that we consider how to change our current systems to become more sustainable. The world's farmers must broaden their perspective and shift conservation concepts and programs to get away from managing for only yield and erosion control and move to managing soil carbon (C) for crop production sustainability and maintaining environmental quality.

Understanding these environmental benefits directly related to soil C and getting the conservation practices implemented on the land will hasten the harmony between man and nature while increasing production of food, fiber and biofuels. This work reviews research on conservation agriculture (CA), tillage-induced C losses and environmental benefits of soil C. Special emphasis is given to the role of the agronomist and the farmer who play a major role in optimizing the canopy conditions to maximize solar energy and C capture for photosynthesis and a major management role in nutrient cycling for optimum crop production and minimum environmental impact. With conservation agriculture, crop residues are left more naturally on the surface to protect the soil and control the conversion of plant C to soil organic matter (SOM) and humus. Carbon is important because it is the backbone of soil organic matter. Conservation agriculture implies conformity with all three principles supporting CA defined by Food and Agriculture Organization of the United Nations (FAO) as:

- minimum soil disturbance,
- diverse crop rotations and/or cover crops and
- continuous plant residue cover.

Conservation agriculture includes concepts of NT (no-till), ZT (zero till) and DS (direct seeding) as the ultimate form of CA.

While the adoption of no-till can lead to the accumulation of soil organic carbon (SOC) in the surface soil layers, a number of recent studies have shown that this effect is sometimes partly or completely offset by greater SOC content near the bottom of the plow layer under full-inversion tillage. The literature in which SOC profiles had been measured under paired NT and full-inversion tillage situations found that profiles of SOC had to be measured to at least 30 cm and preferably >60 cm in most studies. SOC content was generally significantly greater under NT than full-inversion tillage in the surface soil layers. Significant differences in SOC stocks between plow tillage and NT situations occur at the soil surface but also at depth, which further highlights the importance of taking into account the whole soil profile when comparing soil C stocks. The extent, mechanisms and factors controlling SOC stabilization at depth require further investigations for all types of tillage implements, especially inversion tillage.

The impact of NT on nitrous oxide (N_2O) emissions can be significant because of the higher global warming potential. Reviewing the recent literature indicates that on the lighter textured soils, sandy loam to silty clay loams, emissions from NT were generally smaller than from plow tillage systems. However, with heavy clay soils in cool, wet climates, no-till can have higher emissions. The largest contributing factor is the time from nitrogen application which suggests that most of the emissions occur shortly after application.

Recent studies involving dynamic chambers, various tillage methods and associated incorporation of residue in the field indicated major C losses immediately following intensive tillage. The moldboard plow had the roughest soil surface, the highest initial carbon dioxide (CO_2) flux and maintained the highest flux throughout the 19-day study. High initial CO_2 fluxes were more closely 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. The large gaseous losses of soil C following moldboard plowing compared to relatively small losses with direct seeding (no-till) have shown why crop production systems using moldboard plowing have decreased SOM and why no-till or direct seeding crop production systems are slowing that trend. The short-term cumulative CO_2 loss was related to the soil volume disturbed by the tillage tools. The results suggest environmental benefits and C storage of strip tillage over broad area tillage that need to be considered in soil management decisions.

The average short-term C loss from four CA tools was 31% of the CO_2 from the moldboard plow. The moldboard plow lost 13.8 times more CO_2 than the soil not tilled, while conservation tillage tools averaged about 4.3 times more CO_2 loss. The smaller CO_2 loss from CA tools was significant and suggests progress for enhanced soil C management.

If conservation efforts continue with emphasis on C management, we stand a better chance of feeding the world if we understand that carbon is the "C" that starts "C"onservation. Even if C sequestration is questionable in some continuous NT systems on soils of the world, forms of CA are an important new technology that improves soil processes, controls soil erosion and degradation, reduces production cost, maintains environmental quality and provides food security in a sustainable manner.

The soil is the fundamental foundation of our economy and our existence. Carbon management to reduce our carbon footprint is required to address a complex list of issues including soil, water, air quality, biofuels and climate change. Thus to maintain sustainability of the soil resource, we must think about soil C management and make efforts to maximize soil C input and minimize C loss. Today, we must place emphasis on conservation of all natural resources and additional emphasis on C as a key component in ecosystem stability and environmental quality.