Dr. Paul E. Fixen

How Far Have We Progressed With Precision Agriculture?

We're not as far down a road bumpier than we expected, author claims. However, enironmental pressures will speed its acceptance in making it a permanent fixture.

Summary: *Changes in tillage practices that minimize trips across the field have produced many benefits for producers and the environment. It is well established that reduced or conservation tillage increases soil organic matter. Coupled with reductions in fuel use, increases in soil organic matter may offer help in reducing greenhouse gases. Our study shows that increasing use of conservation tillage may offset U.S. fossil fuel emissions by as much as 1. 1 percent and global changes may reduce up to 16 percent of the annual global fossil fuel emissions.*

One potential method for increasing the amount of carbon held in agricultural soil is the conversion of conventional tillage practices to conservation tillage practices. It is well known that soils hold organic matter, which may have a large influence on the long-term sustainability of soil. Conservation and reduced tillage retain more

crop residue. Conservation and enhancement of soil organic matter are essential for plant nutrition, soil structure and compactibility, and water holding capacity. But soil can also function as either a source of, or a sink for, atmospheric carbon. This is significant when one considers that soil organic matter is the largest terrestrial global carbon pool and affects the atmospheric content of $C0_2$, CH_4, and other greenhouse gases. Thus, soil may have an added important role in holding carbon from the atmosphere, thereby helping to decrease the buildup of greenhouse gases and aid in reducing the possibility of global climate change.

The purpose of this study is to estimate the amount of carbon that can be held in the soil and also conserved by reduced fossil fuel usage by the year 2020 as a result of projected changes in U.S. tillage practices for crop production.

Attractive option

Conservation tillage is an attractive option to farmers because it has the potential to reduce production costs. It does, however, require a higher level of farmer skill and farmer assistance for conservation tillage to succeed. Conservation tillage systems, as defined by the Conservation Technology Information Center (West Lafayette, IN), maintain more than 30 percent residue cover on the soil surface.

No-till management consists of no tillage from after harvest to planting time.

Ridge-till systems use no tillage from after harvest to planting, but crops are planted into tilled ridges and crop residues are left between the ridges.

Mulch-till disturbs the entire soil surface while retaining more than 30 percent crop residue on the ground. In this study, the term minimum tillage is used for mulch-till and ridge-till

Increasing carbon Levels

Soil organic carbon tends to increase with conservation tillage because less organic matter is lost to oxidation from mixing of the soil. Soil temperatures also tend to be lower, which slows decomposition. Amount and kind of crop residues have an effect on soil organic carbon levels.

The stability of carbon held in the soil is illustrated by data obtained from long-term tillage sites.

These experiments show that soil had elevated levels of soil organic matter 100 years after manure additions were stopped.

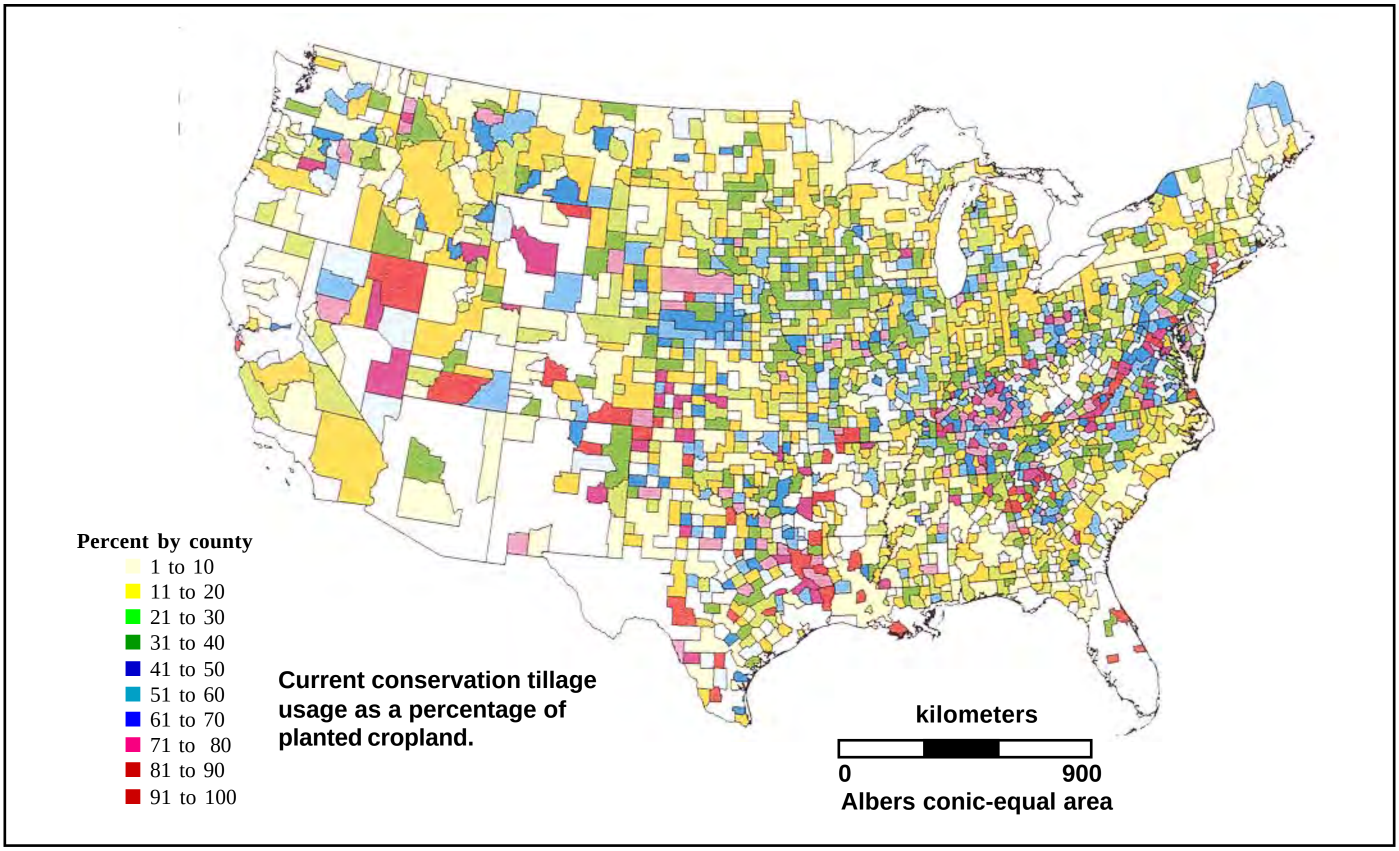
Conservation tillage may increase the amount of soil organic carbon by providing an environment where fungal decomposition is greater than bacterial decomposition. Fungal decomposition results in decomposition products that are more difficult to break into smaller parts than does bacterial decomposition.

Less fossil fuel emissions

In the U.S., fossil fuels used in agriculture emit approximately 84 million tons of carbon each year, excluding emissions from fertilizer and herbicide manufacturing. Fertilizer manufacturing, primarily N, releases about the same amount of carbon.

Conventional tillage systems are the most energy intensive and no-till systems the least. Researchers have estimated that conventional tillage requires the energy equivalent of *7.5* gallons of diesel fuel per acre per year. No-till systems require slightly more than 4 gallons of diesel fuel per acre per year.

Unlike conventionally tilled systems, no-till systems depend more on chemical weed control than on mechanical control. Therefore, a larger percentage of the energy budget for no-till systems is directed to manufacturing herbicides than for conventional tillage systems. Of the diesel fuel equivalent required for no-till, about 70 percent is needed for manufacturing herbicides. In the conventional till-age system, about 23 percent of the energy requirement is allocated to herbicide manufacturing. However, even though herbicide requirements are larger, no-till/



minimum tillage systems are more energy efficient than conventional tillage systems. Less total energy is required to achieve approximately the same crop production under conservation-till. Organic carbon losses from the soil are reduced as are emissions by using less fossil fuel.

Basis of projections

This study incorporated geographic databases of conservation tillage usage and agricultural soil organic carbon with relationships of soil organic carbon dynamics. We used data from published studies to make projections of changes in organic carbon storage under three scenarios of conservation tillage use by the year 2020. The effects on fossil fuel carbon emissions were estimated from changes in fuel usage for field manipulations and herbicides. The details of how we arrived at the conclusions are too complex for this discussion but can be viewed in the full, original text cited under "References" at the end of this article.

Development of the three scenarios mentioned was based on the levels of residue and the amount of cropland under conservation tillage by the year 2020.

Scenario one maintains conservation tillage at current usage of about 27 percent of cropland.

Scenarios two and three incrementally increase conservation tillage usage from current levels to 57 and 76 percent of planted cropland by the year 2020 (Figure 1).

Calculation of carbon costs and savings is based on the estimates of energy requirements of various tillage systems in gallons of diesel fuel equivalents (DFE). These data were converted into amount of carbon per acre per year, using a typical density of No. 2 diesel fuel. Annual crop production carbon units per acre are itemized by field operation and totaled across tillage systems (Table 1).

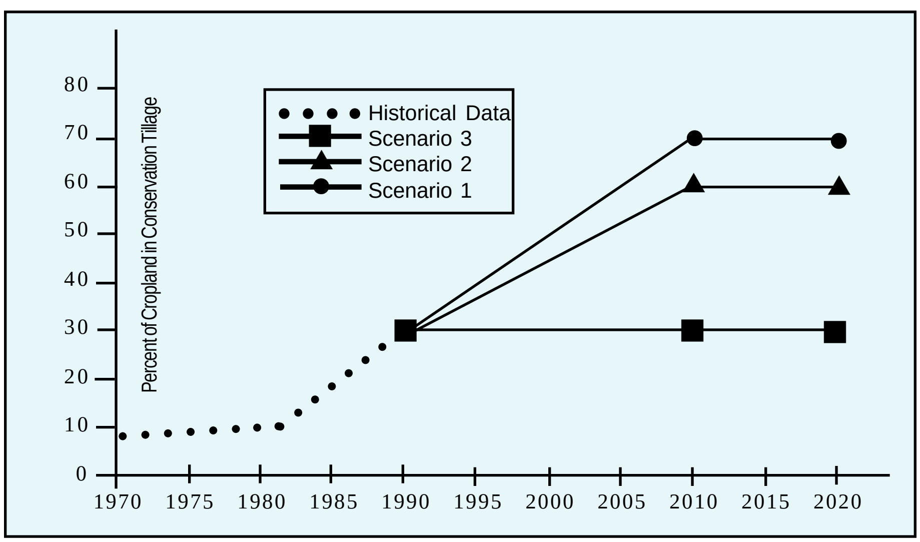


Figure 1. Historic and projected conservation tillage usage to the year 2020 for current levels of conservation tillage at 27% of cropland (scenario 1), and which increases to 57% (scenario 2) and 76% (scenario 3).

Shifting carbon balance

Widespread conversion of major field crop production from conventional to conservation tillage would change the entire system of soil and soil manipulation from a source of atmospheric carbon to a sink for scenario three (Table 2). Increasing the amount of no-till management would change cropland soil from a possible source of atmospheric carbon to a sink for both scenarios two and three.

It is unclear how much of the 34 to 55 million tons of carbon that are projected to be lost from cropland soils for scenario one, as a result of continued conventional tillage, would become atmospheric carbon, because some of it would be eroded and not oxidized. Some of the eroded carbon would be deposited in low-lying areas within the same fields. The remainder of the eroded soil would be deposited by water and wind to other land, drainage channels, streams, and water bodies. The ultimate fate of eroded soil organic carbon has not been extensively studied and this is a topic of great importance.

Of all the tillage types, conventional tillage systems produce the greatest soil organic carbon and fossil fuel carbon losses. Minimum tillage apparently does not lead to additional carbon being held in the soil, but it does prevent a net loss of soil organic carbon. Minimum tillage fuel requirements are not much less than those of conventional tillage. Our estimates show no-till systems increase the amount of carbon held in the soil, as well as reduce fossil fuel carbon emissions.

In our studies, soils with the greatest potential for increasing carbon already had high carbon levels in the upper six inches, such as those soils found in the Pacific Northwest, the Upper Midwest, and northern New England. The regions with low soil organic carbon also had a low amount of field crop production. Thus, there was a net gain rather than a net loss of soil organic carbon for the 3 to 6-inch layer of soil converted to no-till.

Table 1. Average carbon unit for energy associated with crop production.

Operation	Conventional	Chisel plow	Disk	No-till
		--------------lbs carbon/acre/year--------------		
Moldboard plow	11.3			
Chisel plow	7.3			
Disk	4.0	4.0	4.0	
Herbicide application and second disking	4.6	4.6	4.6	
Apply herbicides				0.6
Plant	2.7	2.7	2.7	3.3
Single cultivation	2.7	2.7	2.7	
Herbicide manufacture	10.6	12.6	14.6	17.9
Machinery and repair	11.3	10.0	7.9	4.0
Annual total	47.1	43.9	36.6	25.9
% of conventional	100.0	93.2	77.7	54.9

Table 2. Changes in mean soil organic carbon and fossil fuel carbon emissions (tons C x 10^6) for three scenarios of conservation tillage (CT) usage to the year 2020.

	Scenario 1 27% CT		Scenario 2 57% CT		Scenario 3 76% CT	
Tillage system	Soil	Fuel	Soil	Fuel	Soil	Fuel
Conventional-till	-45	-133	-26	-96	-14	-74
Minimum-till	0	-33	0	-57	0	-73
No-till	0	-7	115	-11	415	-14
Totals	-45	-173	88	-164	401	-161
Net loss or gain	-218		-76		240	

Net gain in soil organic carbon held in both scenarios of reduced tillage (Table 2) is a positive step toward reducing the amount of carbon in the atmosphere. Our highest estimate of soil organic carbon benefit from a tillage conversion would offset approximately 0.7 to 1.1 percent of the U.S. fossil fuel emissions for the same period.

Reducing impact

The release of soil organic carbon globally from agriculture has been estimated at 880 million tons of carbon per year. If alternative tillage practices could prevent this loss, then approximately 16 percent of the annual global fossil fuel emissions would be offset. This offset would be even greater if soil organic carbon increased, as is possible with no-till agriculture. Many additional benefits would be derived from increasing the carbon content of soil, such as increased fertility, stable soil structure, and increased water-holding capacity.

The magnitude of conservation tillage adoption projected in this study is within what appears to be economically and agronomically feasible and is likely to occur regardless of the importance society places on carbon sequestration in soils. Conversion of land to conservation tillage alone is not likely to sequester sufficient carbon to offset the impact of carbon released by non-agricultural fossil fuel consumption. When combined with other strategies of carbon sequestration and fossil fuel emission reductions, widespread implementation of conservation tillage practices may be significant in reducing the impact of global climate change.

References

Kern, J.S.; Johnson, M.G.; "Conservation tillage impacts on national soil and atmospheric carbon levels." Soil Science of America Journal, 57:200-210, 1993.

Kern and Dr. Johnson are soil geographer and soil chemist, respectively, at Man Tech En Environmental Technology, Inc., U.S. EPA Environmental Research Laboratory in Corvallis, Oregon. q