Net Carbon Sequestration in Agriculture: A National Assessment

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Abstract

Agricultural ecosystems have the potential to sequester carbon dioxide from the atmosphere and partially mitigate global climatic change. A full carbon cycle analysis of predominant cropping systems is being conducted to determine potential net carbon sequestration in those systems. Carbon sequestration rates calculated from the full cycle analysis are being used in conjunction with existing land use data sets to determine current and potential carbon storage in the United States. The full cycle analysis completed for a continuous corn crop indicated that there is little difference in the energy used and the carbon emitted between conventional tillage and no-till practices. While the use of farm machinery produces less carbon emissions when using no-till, less carbon is emitted from crop inputs used in conjunction with conventional tillage. No-till practices sequester a larger gross amount of carbon than other tillage intensities, and may sequester a larger net amount of carbon depending on crop type. Preliminary results from a national assessment of 32 long-term experiments indicated an increase in gross carbon sequestration of approximately 168 kg/ha/yr when changing from conventional to no-till practices. Updated rates of carbon sequestration based on analyses of multiple factors (e.g., crop management practices and environmental variables) coupled with a full carbon cycle analysis are expected to provide an accurate basis for policy decisions regarding carbon sequestration initiatives.

Keywords: agricultural energy, carbon dioxide, carbon sequestration, intensive agricultural production, soil organic matter, tillage.

Introduction

Increasing concentration of atmospheric carbon dioxide (CO_2) is considered the predominant cause of global climatic change. It is believed that alternative agricultural practices can partially mitigate increasing CO_2 concentration by sequestering carbon (C) in the soil[1]. Although it is known that certain agricultural practices can sequester C, the temporal and spatial relationships between these practices and the net amount of C sequestered has not been satisfactorily quantified. It is necessary that these relationships be quantified in order to assess the net benefit of C sequestration to society and the individual farmer. Quantitative relationships may also be used as the basis for policies or incentives that encourage C sequestration initiatives.

A national assessment of long-term agricultural experiments that focus on the effects of management practices on soil organic carbon (SOC) is being conducted to quantify current and potential gross soil C sequestration rates at the county level. A full C cycle analysis is being used to quantify C emissions from agricultural inputs which will be used, in conjunction with gross sequestration rates, to determine current and potential future net C sequestration on agricultural lands.

National assessment

The national assessment has two primary objectives. First, to update gross C sequestration rates based on long-term SOC experiments. Lastly, to combine the new gross C sequestration rates with results from the full C cycle analysis to assess the current and potential net C sequestration for the U.S. at the county level. Currently, data from 42 long-term experiments have been collected. The assessment includes analyses of long-term agricultural experiments that monitor changes in soil attributes with changes in agricultural practices. Soil attributes recorded in the data base include, but are not limited to, SOC, total N, bulk density, pH, depth, and texture. Agricultural practices include tillage intensity, crop sequence/rotation, fertilizer use, and other soil amendments. Site history is also documented for use in calculations of temporal SOC changes.

Preliminary analysis of 32 plots from 14 long-term experiments (Fig. 1) indicated that SOC in the top 30 cm increases an average of 168 kg C/ha/yr when changing from conventional tillage to no-till. Average duration of the experiments analyzed was 25 years. In many experiments, SOC increased in the top 10 cm when changing to no-till, while decreasing or remaining the same in the lower 20-30 cm. In addition to the variation of SOC with depth, variation also occurred across crop type. For example, C sequestration rates were higher in corn crops than in all crops combined. Analysis of 9 continuous corn plots indicated an average increase of 595 kg C/ha/yr in the top 30 cm.

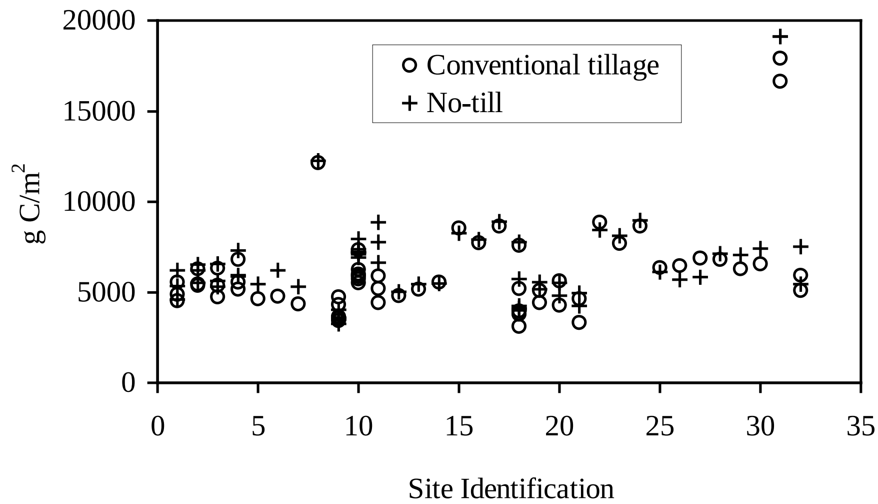

Figure 2. Effects of long-term conventional and no-till practices on SOC. Several symbols for one site represent SOC measurements across a temporal gradient.

In many cases, additional SOC increases the number and size of soil aggregates, soil moisture and, as a result, increases yields. However, there are documented cases where yields remain unchanged with reductions in tillage intensity, and also cases where yields decline. For this reason, yield data is being collected with SOC data when available. A comprehensive analysis of soil attributes, agricultural practices, and yield data are being completed to determine the multiple, and possibly interacting, effects that these variables have on each other.

Full carbon cycle analysis

A full C cycle analysis can be used to calculate net C sequestration based on all significant C exchanges with the atmosphere. Carbon emissions from agriculture come primarily from decomposition of soil organic matter (SOM) and the fuel used to produce, manufacture, and apply agriculture inputs. Agricultural inputs producing C emissions include fertilizers, pesticides, irrigation, and machinery. In addition to soil amendments, tillage intensity can regulate the amount of soil disturbance and the subsequent mineralization of SOM.

Preliminary results from a full C cycle analysis are given for a continuous corn crop (Table 1). Minimum tillage was calculated as emitting the most amount of C from agricultural inputs. While conventional tillage practices emit more C from machinery than no-till, less C is emitted from crop inputs which results in little to no difference in total C emissions.

Although energy inputs and C emissions from inputs to corn crops do not differ much between tillage practices, no-till practices generally sequester more C in the soil due to less soil disturbance, higher soil moisture, and increased biomass inputs from surface residues. The gross C sequestration value used for corn, taken from the national assessment data, is 595 kg C/ha/yr. Calculations based on gross C sequestration and C emission rates indicated that corn crops using no-till practices have the potential to sequester an additional net 288 kg C/ha/yr compared to conventional tillage.

Table 1. Annual gross C emissions from crop management practices for corn under three tillage intensities.*

	% acres treated	Conventional till	Minimum till	No-till
			kg C/ha	
Agricultural machinery:				
Moldboard plow	-	24.63	-	-
Disc (twice)	-	15.08	15.08	-
Planting	-	5.58	5.58	5.58
Single cultivation	-	3.69	3.69	-
Harvest w/ combine	-	12.59	12.59	12.59
Manufac., transport., and repair of machinery	-	7.29	5.60	4.01
Machinery total	-	68.86	42.54	22.18
Crop inputs:				
Herbicide PPTA†	96	15.96	17.44	21.38
Insecticide PPTA	24	5.95	5.10	4.08
N PPTA	96	104.75	144.08	146.22
P_2O_5 PPTA	81	17.22	20.32	19.31
K_2O PPTA	72	14.44	18.39	16.63
Lime PPTA	5	606.90	606.90	606.90
Seed production	100	47.70	47.70	47.70
Irrigation	15	132.79	119.53	106.24
Input weighted average‡	N/A	236.33	286.77	285.51
Total	N/A	305.19	329.31	307.69

*National averages for crop inputs based on 1995 survey data. †PPTA (production, package, transportation, and application). ‡Weighted averages for fertilizers and pesticides were based on separate percentage rates for different tillage intensities[2,3], not on percentages averaged across tillage practices shown in the table.

In this full cycle analysis, it is assumed that the rate of C sequestration begins to decline after 20 years to reach a new relative equilibrium in approximately 40 years. Using this scenario, additional SOC content stabilizes at 18,000 kg/ha (Fig. 2). While SOC content stabilizes, C emissions from crop inputs continue, resulting in a decline of the net C sequestered. During the decline in net C sequestered, there is a net emission of C to the atmosphere. In comparison to conventional tillage practice, conversion to no-till in the 60 year period reduced C emissions to the atmosphere by approximately 17,325 kg/ha.

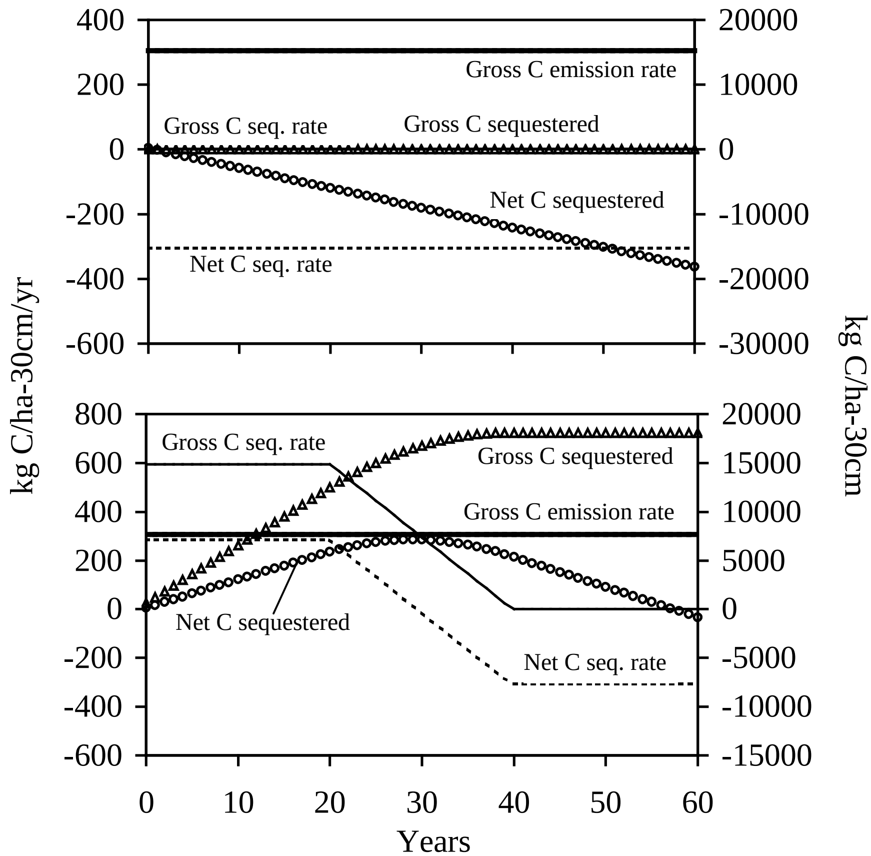

Figure 2. Full C cycle dynamics for U.S. corn crop with conventional tillage (top) and no-till (bottom). Note: Rates coincide with values on primary y-axis (left) while gross and net C sequestered coincide with values on secondary y-axis (right). Gross C sequestered refers to SOC gained in addition to what existed prior to changes in tillage practice.

Discussion and Conclusions

Rates of gross C sequestration coupled with full C cycle analyses will provide better estimates of current and potential net C sequestration at the county level. A full cycle analysis of C dynamics in corn production indicated that C emitted from no-till practices does not differ significantly from conventional tillage emissions. However, results vary between crop types. A similar analysis for a continuous wheat crop, not presented here, indicates that total emissions from conventional tillage practices are significantly greater than both minimum tillage and no-till. Preliminary analyses indicated that the potential to sequester carbon varies considerably between crop type, crop rotation, and the amount of fertilizer necessary for crop growth. Regardless of crop type or soil depth, data suggests an increase in SOC within the 0-30 cm depth using no-till. The lower gross C sequestration value obtained in an analysis using all crop types suggests that net C sequestration from cereal grains may be much smaller than that from continuous corn crops.

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