Soil Organic Carbon Sequestration in Cotton Production Systems

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Abstract

Conservation tillage, crop intensification, sod-based rotations, and judicious application of fertilizers and herbicides are agricultural practices that are not only agronomically sound, but could increase soil organic C (SOC) sequestration. These practices have great potential for adoption by cotton (*Gossypium hirsutum L*) producers in the southeastern USA. We calculated potential SOC sequestration under different management scenarios of five major land resource areas in the southeastern USA using the Soil Conditioning Index (SCI), a decision tool currently used by USDA-Natural Resources Conservation Service. The SCI will be used to determine payments to farmers enrolling in the Conservation Security Program. All cotton cropping systems with conventional tillage would lead to loss of SOC. Growing cotton in monoculture with no tillage could lead to a small loss, no change, or a small increase in SOC, depending upon major land resource area, slope, and soil texture. The SCI predicted larger changes in SOC whenever no-tillage management was combined with cover cropping and cotton was rotated with high-residue-producing crops. Cotton producers in eligible watersheds of the Conservation Security Program could expect to receive an average of $3.36/acre, with payments up to $8/acre, depending on practices employed and soil conditions. Soil organic C is important to maintain high soil quality, to improve crop productivity, and to mitigate greenhouse gas emission. Further agricultural research and extension activities are needed to capture the full benefits of SOC sequestration for agronomic, environmental, and economic sustainability.

Introduction

With sound soil and crop management, the potential for SOC sequestration in the southeastern USA may be higher than in more temperate regions of North America (Franzluebbers, 2005), because the warm and humid climate with a long growing season allows for high cropping intensity and biomass production, which translates into high potential for photosynthetic C fixation (Reeves and Delaney, 2002). Surface residue management is especially critical in the southeastern USA, because soils are highly erodible and high-energy rainstorms occur during the growing season (Blevins et al., 1994). Soils of the region have low SOC, partly because of the prevailing climatic conditions and soil mineralogy (Jenny, 1930), but also due to historical mismanagement that exposed the soil surface to rapid biological oxidation and extreme soil erosion (Trimble, 1974; Harden et al., 1999). Cotton is one of the most important crops in Alabama, Georgia, Mississippi, and Texas. Cotton production has high potential profitability, but historically has been detrimental regarding sustainability of natural resources for the region (Reeves, 1994).

Conservation tillage

When crop residues and cover-crop mulch are left on the surface, they protect the soil against erosion, increase water infiltration, decrease soil water evaporation, and increase SOC at the surface. Plant residues decompose slower on the soil surface than when incorporated into soil. Conservation tillage coupled with efficient management of inputs could lead to sequestration of SOC and greater cotton lint and seed yield. Reviewing literature comparing SOC under no tillage compared with conventional tillage in cotton production systems of the southeastern USA, Causarano et al. (2005) obtained an average rate of 428 lb C/acre/yr.

Crop Rotation and Cover Cropping

When practiced in monoculture or even in double cropping, conservation tillage is an imperfect and incomplete system. Perhaps more than any other crop, good residue management is critical in cotton, because of its sparse residue production. Good residue management can be achieved with a sound crop rotation and use of cover crops in combination with conservation tillage. Unfortunately, higher profitability of cotton in relation to other cropping alternatives often leads to cotton monoculture (Reeves, 1994). The 'Old Rotation' experiment at Auburn University was initiated in 1896 to determine (1) the effect of rotating cotton with other crops to improve yields and (2) the effect of winter legumes in cotton production systems (Mitchell and Entry, 1998). Seed cotton yield during a 10-year period from 1986-1995 was greater in rotation with corn (*Zea mays* L.) and winter legumes than under monoculture cropping. Mitchell and Entry (1998) demonstrated a positive association of SOC with cotton seed yield, suggesting that higher biomass inputs from cover crops and corn in rotation with cotton improved SOC sequestration and cotton productivity. With the introduction of conservation tillage to the experiment in 1995, the benefits of crop rotations and cover crops to cotton productivity and SOC concentration have been enhanced (Mitchell et al., 2002; Siri-Prieto et al., 2002).

Fertilizers and Manures

Fertilizer or manure application would be expected to increase SOC, because of greater C input associated with enhanced primary production and crop residues returned to the soil. Using available data from six literature sources of various crops in the region, Franzluebbers (2005) estimated that the net C offset due to N fertilization could be optimized at 214 lb C/acre/yr with the application of 95 lb N/acre/yr. This N rate is within the range of extension recommendations for cotton in most southeastern USA states.

Nutrients from animal manure (e.g. poultry litter, confined dairy, or beef cattle) represent a valuable agricultural resource that is not currently widely and fully utilized. Nyakatawa et al. (2001) suggested that poultry litter application to cropping systems with winter annual cover crops could be an environmentally suitable practice to reduce reliance on commercial fertilizer and dispose of large quantities of waste from a burgeoning poultry industry. Endale et al. (2002) found that combining no tillage with poultry litter application produced up to 50% greater cotton lint than conventionally tilled and fertilized cotton in the Southern Piedmont. Application of dairy manure increased SOC (1.2 tons/acre) in a cotton-corn rotation with cover crops in the Coastal Plain (J. Terra, unpublished data).

Sod-Based Crop Rotation

Soil organic C sequestration under grass management systems in the southeastern USA can exceed sequestration rates observed under crop management systems. From 12 observations of various grass establishment studies, SOC sequestration was 917 $\pm$ 802 lb C/acre/yr during an average of 15 years of investigation (Franzluebbers, 2005). Rotation of crops with pastures could take advantage of high SOC and promote higher productivity under ideal condition, because surface soil would be enriched in soil organic matter and organically bound nutrients, some weed pressures could be reduced, soil water storage could be enhanced, and disease and pest pressures could be reduced. Successful crop and pasture rotation systems have been developed with conservation tillage in South America (Diaz-Zorita et al, 2002; Garcia-Prechac et al., 2004). These studies have demonstrated that SOC can be preserved following rotation of pasture with crops when using conservation tillage. At the Wiregrass Research and Extension Center in Alabama, SOC concentration of the surface 2 inches in a long-term cotton-peanut (*Arachis hypogaea L*) rotation (initially 0.76 %) increased to 0.94 % following introduction of winter annual pasture [oat (*Avena sp*) or ryegrass (*Lolium sp*)] for three years (G. Siri-Prieto, unpublished data). Winter-annual grazing in rotation with cotton also increased net returns.

PREDICTING SOIL ORGANIC C CHANGES IN COTTON PRODUCTION SYSTEMS

The Soil Conditioning Index (SCI) is a tool currently used by the USDA-Natural Resources Conservation Service to predict trends in SOC, as affected by cropping system and tillage management (Hubbs et al., 2002). The SCI has been incorporated into the Revised Universal Soil Loss Equation (RUSLE2) to assist district staff members of the Natural Resources Conservation Service working with local producers to plan and design crop and residue management practices for overcoming issues of low soil organic matter, poor soil tilth, and other soil quality-related problems. When SCI is negative, SOC is predicted to decline. When SCI is positive, SOC is predicted to increase. The magnitude of the SCI value is more related to the probability of achieving a change rather than determining an absolute value of that change. The SCI is being used by the USDA–Natural Resources Conservation Service to calculate payments to landowners enrolled in the Conservation Security Program. In the following, we present some scenarios of common crop and tillage management systems being used in five major land resource areas of the southeastern USA. All cropping systems included cotton as a primary crop, either in monoculture or in rotation with other common crops of the region.

Appalachian Ridges and Valleys (Tennessee Valley)

Continuous cotton production in the Tennessee Valley of northern Alabama would cause loss of SOC under both chisel plow and conservation tillage (Table 1), although the extent of loss would likely be greater with inversion tillage than with conservation tillage. By including a cover crop in a cotton-corn rotation, SOC would more likely increase. Even with soil disturbance with a bent-leg subsoiler (paratill) prior to cotton planting, including a cover crop in the cropping system could help to promote SOC sequestration. Soil compaction can be a problem in the Tennessee Valley region, where soils have platy structure, leading to high penetration resistance, especially under no tillage. Cotton yield reductions were common under no tillage and jeopardized the adoption of this technology in the early 1990s when the common practice was to plant without tillage directly into cotton stubble with no winter cover crop. It was later demonstrated that non-inversion tillage under the row in the autumn coupled with a rye cover crop to reduce compaction and provide moisture-conserving surface residue could increase yield (Raper et al. 2000a, b; Schwab et al., 2002).

Table 1. Management scenarios and soil conditioning index (SCI) for the Appalachian Ridges and Valleys region.

Location	Soil Series	Soil Texture [a]	Slope (%)	Scenario	SCI
Belle Mina AL	Decatur	SiL	3	Continuous cotton, fall chisel plow	-2.60
				Continuous cotton, no tillage	-0.36
				Cotton/rye cover-corn/rye cover	0.17
				Cotton/rye cover-corn/rye cover, paratill prior to cotton	0.09

[a] SiL is silt loam.

Coastal Plain

All conventional-tillage scenarios in the Coastal Plain region would cause loss of SOC (Table 2). Soil management strategies to increase SOC sequestration included the use of conservation tillage, greater cropping diversity with high residue-producing crops such as corn and cover crops, application of animal manure, and inclusion of sod-based rotations. Subsoiling with paratill has been found to help alleviate soil compaction due to traffic and natural reconsolidation, which can constrain root growth in many Coastal Plain soils. However, when paratill was simulated in monoculture cotton with conservation-tillage planting at Shorter AL, SOC was predicted to decline. Only in a cotton-corn rotation was SCI positive when paratill was performed.

Table 2. Management scenarios and soil conditioning index (SCI) for the Coastal Plain region. CT is conventional tillage and NT is no tillage.

Soil Series	Slope (%)	Soil Texture [a]	Location / Scenario	SCI: Monoculture Cotton CT	SCI: Monoculture Cotton NT	SCI: Rotated Cotton [b] NT
Bendale	2	SL	Brewton AL	-1.2	0.21	0.50
Norfolk	3	LS	Florence SC	-0.41	0.44	0.60
Norfolk	4	LS	Goldsboro NC	-0.62	0.31	0.58
Dothan	2	SL	Headland AL	-0.94	0.23	0.54
Bama	2	SL	Shorter AL, no manure, no paratill	-0.84	0.28	0.54
			With manure, no paratill	-0.63	0.47	0.60
			No manure, with paratill	-0.84	-0.27	0.45
			Intensive rotation [c], no paratill			0.65

[a] LS is loamy sand, SL is sandy loam. [b] Base rotation is cotton / rye cover – corn / rye cover.
[c] Similar rotation to that described in Reeves and Delaney (2002): corn / sun hemp cover / wheat – cotton / white lupin + crimson clover cover.

Mississippi Valley: Silty Uplands and Alluvium Land Areas

All conventional-tillage scenarios in the Mississippi Valley region would cause loss of SOC (Table 3). Steep slope in Senatobia MS contributed to the large negative SCI under conventional tillage and small negative SCI even under no tillage. With silt loam texture of soils in the region, these soils are highly susceptible to C loss by erosion. Conservation tillage and rotation of cotton with high residue-input crops such as corn and cover crops are key management tools for maintaining adequate infiltration and reducing soil erosion. Mutchler et al. (1985) measured 33 ton/acre/yr of soil loss from conventional-tillage cotton, but only 5 ton/acre/yr) of soil loss from reduced-tillage and no-tillage cotton. Triplett et al. (1996) found that seed-cotton yield was greater under conventional tillage during the 1st year, but was greater under no tillage during the 2nd through 4th years. These data suggest that the benefits of conservation tillage on productivity and SOC can be successfully developed with time due to a change in soil physical, chemical, and biological properties.

Table 3. Management scenarios and soil conditioning index (SCI) for the Mississippi Valley region. CT is conventional tillage and NT is no tillage.

Soil Series	Slope (%)	Soil Texture [a]	Location	SCI Monoculture Cotton CT	SCI Monoculture Cotton NT	SCI Rotated Cotton [b] NT
Grenada	5	SiL	Senatobia MS	-8.4	-1.9	0.07
Gigger	2	SiL	Winnsboro LA	-1.9	0.03	0.11
Dundee	2	SiL	Stoneville MS	-1.9	0.36	0.42
Commerce	2	SiL	St. Joseph LA	-1.5	0.08	0.52

[a] SiL is silt loam. [b] Cotton / wheat cover – corn / wheat cover

Southern Piedmont

All conventional-tillage scenarios in the Southern Piedmont region would cause loss of SOC (Table 4). Monoculture cotton production with conservation tillage would increase SOC, but including a winter cover crop or grain in the rotation would enhance SOC sequestration even further. Increasing crop rotation complexity with short-term sod would have high potential for SOC sequestration. In the Southern Piedmont, cotton was the dominant crop for more than 150 years and soil-erosion scars in this sloping physiographic region suggest that crop residues were poorly managed during this period (Langdale et al., 1994). Despite adequate rainfall, high water runoff and crusting contribute to low soil water storage under conventional tillage. Hence, maintaining sufficient residue cover is particularly important for reducing surface sealing, water runoff, soil loss, and runoff of agricultural chemicals (Raczkowski et al., 2002). Research on these soils has demonstrated that conservation tillage leads to greater SOC storage, improvement in soil quality, and greater cotton yield (Franzluebbers et al., 1999; Schomberg et al., 2003). Deep tillage (such as subsoiling without inversion of soil) may be required only initially during transition to conservation tillage management to overcome the lack of soil structure following decades of intensive tillage.

Table 4. Management scenarios and soil conditioning index (SCI) for the Piedmont region.

Location	Soil Series	Soil Texture [a]	Slope (%)	Scenario	SCI
Watkinsville GA	Cecil	SL	4	Monoculture cotton, spring-chisel tillage	-1.10
				Monoculture cotton, no tillage	0.12
				Cotton – corn – corn – tall fescue pasture	0.61
Auburn AL	Marvyn	LS	3	Monoculture cotton, fall-disk tillage	-0.82
				Monoculture cotton, no tillage	0.27
				Cotton / grazed rye cover, no tillage	0.42

[a] LS is loamy sand, SL is sandy loam.

Eastern Texas: Blackland Prairie, Gulf Coast Prairies, and Lower Rio Grande Plain Land Areas

All conventional-tillage scenarios in the eastern Texas region would cause loss of SOC (Table 5). Adoption of conservation tillage would enhance SOC in these fine-textured soils. Rotating cotton with corn using conservation tillage would lead to even greater potential for SOC sequestration. The relatively small difference between monoculture cotton and rotated cotton using conservation tillage is probably because no cover crop was simulated. Although the drier climatic condition in this region might limit the successful incorporation of a cover crop in the rotation, efforts to develop this technology would probably be beneficial for potential SOC sequestration.

Table 5. Management scenarios and soil conditioning index (SCI) for the eastern Texas region.

				Scenario		
				Monoculture Cotton		Rotated Cotton [b]
Soil Series	Slope (%)	Soil Texture [a]	Location	CT	NT	NT
Houston Black	2	C	Temple TX	-1.10	0.55	0.53
Orelia	2	CL	Corpus Christi TX	-0.71	0.26	0.36
Hidalgo	2	SCL	Weslaco TX	-0.70	0.41	0.51

[a] C is clay, CL is clay loam, SCL is sandy clay loam. [b] Base rotation is cotton – corn.

INCENTIVE PROGRAMS TO FOSTER SOIL ORGANIC C SEQUESTRATION

Current government incentive programs do not specifically address SOC sequestration. The following two programs are administered by the USDA–Natural Resources Conservation Service and indirectly address SOC sequestration in agricultural production systems.

Environmental Quality Incentives Program (EQIP)

Provides financial and technical assistance to farmers and ranchers who adopt environmentally sound practices on eligible agricultural land. National priorities addressed by EQIP are:

- reduction of non-point source pollution such as nutrients, sediment or pesticides
- reduction of groundwater contamination
- conservation of ground and surface water resources
- reduction of greenhouse gas emissions
- reduction in soil erosion and sedimentation from unacceptable levels on agricultural land
- promotion of habitat conservation for at-risk species

Contracts provide incentive payments and cost-sharing to implement conservation practices subject to technical standards adapted for local conditions.

Conservation Security Program (CSP)

This voluntary program provides financial and technical assistance to agricultural producers who conserve and improve the quality of soil, water, air, energy, plant and animal life, and support other conservation activities. Soil and water quality practices include conservation tillage, crop rotation, cover cropping, grassed waterways, wind barriers, and improved nutrient, pesticide, or manure management. Maximum annual payments vary from $20,000 to $45,000, depending on the tier of participation. Contracts are valid for 5 to 10 years.

In fiscal year 2004, the CSP provided funding to 18 watersheds in the USA. About 27,300 farms and ranches were within these watersheds, covering 14 million acres. In the southeastern USA, three watersheds were targeted: (1) Hondo River in Texas, (2) Little River in Georgia, and (3) Saluda River in South Carolina. An enrolled landowner in one of these watersheds would receive a payment of the SCI value for practices employed times $11.60/acre, up to a maximum SCI value of 2.5. Cotton farmers using conservation tillage could be expected to receive anywhere from no payment to $8/acre with an average of $3.36/acre based on SCI values derived from Tables 1-5.

CONCLUSIONS

Current and future agricultural management systems could help to mitigate greenhouse gas emission by sequestering greater quantities of C in soil organic matter with the adoption of conservation practices. Using the Soil Conditioning Index (SCI) to predict changes in soil organic C (SOC), almost all cotton cropping systems with conventional tillage would lead to loss of SOC. Growing cotton in monoculture with no tillage could lead to a small loss, no change, or a small increase in SOC, depending upon major land resource area, slope, and soil texture. The SCI predicted larger changes in SOC whenever no-tillage management was combined with cover cropping and cotton was rotated with high-residue-producing crops. The SCI will be used to determine payments to farmers enrolling in the Conservation Security Program, administered by the USDA–Natural Resources Conservation Service. Cotton producers in eligible watersheds could expect to receive an average of $3.36/acre, with payments up to $8/acre, depending on practices employed and soil conditions.

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REFERENCES

Blevins, R.L., W.W. Frye, M.G. Wagger, and D.D. Tyler. 1994. Residue management strategies for the Southeast. p. 63-76. *In* J.L. Hatfield and B.A. Stewart (Eds.) Crops Residue Management. Lewis Publishers, Boca Raton, FL.

Causarano, H.J., A.J. Franzluebbers, D.W. Reeves, J.N. Shaw, and M.L. Norfleet. 2005. Potential for soil carbon sequestration in cotton production systems of the southeastern USA. *In* Proc. Beltwide Cotton Conf., New Orleans, LA, 4-7 January 2005.

Diaz-Zorita, M., G. Duarte, and J.H. Grove. 2002. A review of no-till systems and soil management for sustainable crop production in the subhumid and semiarid Pampas of Argentina. Soil Tillage Res. 65:1-18.

Endale, D.M., M.L. Cabrera, J.L. Steiner, D.E. Radcliffe, W.K. Vencill, H.H. Schomberg, and L. Lohr. 2002. Impact of conservation tillage and nutrient management on soil water and yield of cotton fertilized with poultry litter or ammonium nitrate in the Georgia Piedmont. Soil Tillage Res. 66:55-68.

Franzluebbers, A.J. 2005. Soil organic carbon sequestration and agricultural greenhouse gas emissions in the southeastern USA. Soil Tillage Res. (in press).

Franzluebbers, A.J., G.W. Langdale, and H.H. Schomberg. 1999. Soil carbon, nitrogen, and aggregation in response to type and frequency of tillage. Soil Sci. Soc. Am. J. 63:349-355.

Garcia-Prechac, F., O. Ernst, G. Siri-Prieto, and J.A. Terra. 2004. Integrating no-till into crop-pasture rotations in Uruguay. Soil Tillage Res. 77:1-13.

Harden, J.W., J.M. Sharpe, W.J. Parton, D.S. Ojima, T.L. Fries, T.G. Huntington, and S.M. Dabney. 1999. Dynamic replacement and loss of soil carbon on eroding cropland. Global Biogeochem. Cycles 13:885-901.

Hubbs, M.D., M.L. Norfleet, and D.T. Lightle. 2002. Interpreting the soil conditioning index. p. 192-196. *In* E. van Santen (Ed.) Making Conservation Tillage Conventional: Building a Future on 25 years of Research, Proc. 25th Annual Southern Conserv. Tillage Conf. Sustainable Agric., Auburn, AL, 24-26 June 2002.

Jenny, H. 1930. A study on the influence of climate upon the nitrogen and organic matter content of the soil. Missouri Agric. Expt. Sta. Res. Bull. 152.

Langdale, G.W., E.E. Alberts, R.R. Bruce, W.M. Edwards, and K.C. McGregor. 1994. Concepts of residue management infiltration, runoff, and erosion. p. 109-124. *In* J.L. Hatfield and B.A. Stewart (Eds.) Crops Residue Management. Lewis Publishers, Boca Raton, FL.

Mitchell, C.C., and J.A. Entry. 1998. Soil C, N and crop yields in Alabama's long-term 'Old Rotation' cotton experiment. Soil Tillage Res. 47:331-338.

Mitchell, C.C., D.W. Reeves, and D. Delaney. 2002. Conservation tillage in Alabama's "Old Rotation". p. 30-35. *In* E. van Santen (Ed.) Making Conservation Tillage Conventional: Building a Future on 25 years of Research, Proc. 25th Annual Southern Conserv. Tillage Conf. Sustainable Agric., Auburn, AL, 24-26 June 2002.

Mutchler, C.K., L.L. McDowell, and J.R. Johnson, J.R. 1985. Erosion from reduced-till cotton. p. 156-158. *In* W.L. Hargrove, F.C. Boswell, and G.W. Langdale (Eds.) Proc. 1985 Southern Region No-Till Conf., Griffin, GA.

Nyakatawa, E.Z., K.C. Reddy, and G.F. Brown. 2001. Residual effect of poultry litter applied to cotton in conservation tillage systems on succeeding rye and corn. Field Crops Res. 71:159-171.

Raczkowski, C. W., G.B. Reddy, M.R. Reyes, G.A. Gayle, W. Busscher, P. Bauer, and B. Brock. 2002. No-tillage performance on a Piedmont soil. p. 273-276. *In* E. van Santen (Ed.) Making Conservation Tillage Conventional: Building a Future on 25 years of Research, Proc. 25th Annual Southern Conserv. Tillage Conf. Sustainable Agric., Auburn, AL, 24-26 June 2002.

Raper, R.L., D.W. Reeves, C.H. Burmester, and E.B. Schwab. 2000a. Tillage depth, tillage timing, and cover crop effects on cotton yield, soil strength, and tillage energy requirements. Appl. Eng. Agric. 16:379-385.

Raper, R.L., D.W. Reeves, E.B. Schwab, and C.H. Burmester. 2000b. Reducing soil compaction of Tennessee Valley soils in conservation tillage systems. J. Cotton Sci. 4:84-90.

Reeves, D.W., and D.P. Delaney. 2002. Conservation rotations for cotton production and carbon storage. p. 344-348. *In* E. van Santen (Ed.) Making Conservation Tillage Conventional: Building a Future on 25 years of Research, Proc. 25th Annual Southern Conserv. Tillage Conf. Sustainable Agric., Auburn, AL, 24-26 June 2002.

Reeves, D.W. 1994. Cover crops and rotations. p. 125-172. *In*: J.L. Hatfield and B.A. Stewart (Eds.) Crops Residue Management. Lewis Publishers, Boca Raton, FL.

Schomberg, H.H., G.W. Langdale, A.J. Franzluebbers, and M.C. Lamb. 2003. Comparison of tillage types and frequencies for cotton on Southern Piedmont soil. Agron. J. 95:1281-1287.

Schwab, E.B., D.W. Reeves, C.H. Burmester, and R.L. Raper. 2002. Conservation tillage systems for cotton in the Tennessee Valley. Soil Sci. Soc. Am. J. 66:569-577.

Siri-Prieto, G., D.W. Reeves, J.N. Shaw, and C.C. Mitchell. 2002. Impact of conservation tillage on soil carbon in the 'Old Rotation'. p. 277-282. *In* E. van Santen (Ed.) Making Conservation Tillage Conventional: Building a Future on 25 years of Research, Proc. 25th Annual Southern Conserv. Tillage Conf. Sustainable Agric., Auburn, AL, 24-26 June 2002.

Trimble, S.W. 1974. Man-induced soil erosion on the Southern Piedmont, 1700-1970. Soil Conserv. Soc. Am., Ames, IA, 180 pp.

Triplett, G.B., Jr., S.M.Dabney, and J.H. Siefker. 1996. Tillage systems for cotton on silty upland soils. Agron. J. 88:507-512.