Assessing Soil Organic Carbon (SOC) Sequestration with the Soil Conditioning Index (SCI) in the Southeastern USA

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Financial Support

USDA-ARS Soils CRIS (6612-11120-003-00D)
"Soil Organic Matter and Nutrient Cycling to Sustain Agriculture in the Southeastern USA"

Cotton Incorporated (Project No. 05-712)
"Potential for Soil Carbon Sequestration in Cotton Production Systems of the Southeastern USA"

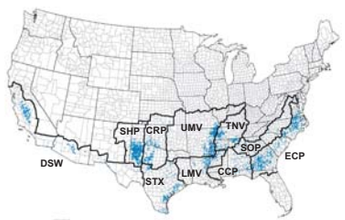
Objectives

(1) Estimate potential soil organic C sequestration under conventional and conservation management of cotton cropping systems in counties throughout the Cotton Belt using the recently calibrated soil conditioning index model (Box 1).

(2) Evaluate if soil type and climatic conditions might alter management-induced soil organic C sequestration (i.e. do environmental conditions have a greater influence than management conditions in affecting change in soil organic C).

Methods

- RUSLE2 (Revised Universal Soil Loss Equation) was used to obtain estimates of soil conditioning index (SCI) values for a set of cotton management systems throughout the Cotton Belt of the southern USA.
- Using the Census of Agriculture from the USDA - National Agricultural Statistics Service, counties with land harvested for cotton in 2007 were selected for simulation (n = 469).
- County-specific climate data and a randomly selected soil type were used for each simulation. Slope of land (maximum allowed of 15%) was determined by the soil type selected.
- A set of 7 standard cropping systems was simulated in each county:
  - CT1 - Conventional-tillage continuous cotton
  - NT1 - No-tillage continuous cotton
  - NT2 - No-tillage continuous cotton with winter cover crop
  - NT3 - No-tillage cotton-cotton-peanut-corn rotation with winter cover crop
  - NT4 - No-tillage cotton-corn-wheat/soybean rotation with winter cover crop
  - NT5 - No-tillage cotton-cotton-clover/grass hay-grass pasture-corn rotation with winter cover crop
  - P1 - Permanent perennial pasture with rotational grazing
- Counties were grouped into 10 broad regions, which spanned one or more crop management zones (CMZs) used by RUSLE2:
  - DSW - Desert Southwest (23, 33, 34, 43), n = 28
  - SHP - Southern High Plains (5, 15, 19), n = 41
  - STX - South Texas (37.1, 38.1, 41, 44, 57, 58), n = 49
  - CRP - Central Rolling Plains (40, 48), n = 55
  - LMV - Lower Mississippi Valley (37, 38), n = 33
  - UMV - Upper Mississippi Valley (17, 42), n = 36
  - CCP - Central Coastal Plain (69), n = 31
  - TNV - Tennessee Valley (63), n = 44
  - ECP - Eastern Coastal Plain (67), n = 130
  - SOP - Southern Piedmont (66), n = 22
- Separate simulations were run to assess the relative effects of slope (1, 5, and 9%) and soil texture (gradient of clay concentration) on SCI under four management systems (gradient of disturbance) and four regions (gradient of climatic conditions).
- Separate simulations were also run to test the relative effects of climatic conditions (200-1500 mm precipitation) and slope (1 and 5%) on SCI in three management systems (moldboard-plowed cotton, no-tillage cotton with wheat cover crop, and rotationally grazed perennial pasture).
- Orthogonal contrasts were constructed within an analysis of variance to test:
  - Conservation vs conventional tillage (CT1 vs all others)
  - Cropping vs grass (NT1+2+3+4+5 vs P1)
  - Monoculture vs rotated cotton (NT1+2 vs NT3+4+5)
  - With vs without cover cropping in monoculture cotton (NT1 vs NT2)
  - Cotton 1-in-3 years vs more often (NT4 vs NT3+5)
  - Cotton rotated with peanut vs rotated with grass (NT3 vs NT5)



Results

Table 1
Characteristics of cotton production in each of the 10 different regions of the Cotton Belt from the 2007 Census of Agriculture.

Characteristic	Desert Southwest	Southern High Plains	South Texas	Central Rolling Plains	Lower Mississippi Valley	Upper Mississippi Valley	Central Coastal Plain	Tennessee Valley	Eastern Coastal Plain	Southern Piedmont	All regions
	Region of Cotton Belt										
No. counties	28	41	49	55	33	36	31	44	130	22	469
No. farms	1428	4105	1828	1622	893	1854	818	1216	4367	211	18 605
Land in cotton (Mha)	0.30	1.22	0.36	0.36	0.20	0.65	0.12	0.29	0.68	0.03	4.25
Land in cotton (ha farm^{-1})	180 ± 103	244 ± 121	172 ± 110	167 ± 101	213 ± 109	326 ± 135	155 ± 67	218 ± 105	154 ± 67	126 ± 66	189 ± 108
Irrigated land (%)	97	46	12	19	26	70	5	3	19	1	38
Cotton yield (bales ha^{-1})	6.8 ± 1.4	4.7 ± 1.0	4.0 ± 1.0	3.6 ± 1.0	4.8 ± 0.6	5.2 ± 0.7	2.9 ± 0.9	3.1 ± 0.9	3.8 ± 1.1	3.0 ± 1.2	4.1 ± 1.4

Data for regions were from 2007 and only if land area was reported for a county. Land in cotton (ha / farm) and cotton yield (bales / ha) are mean + standard deviation among county-level values. Regions were defined from RUSLE2 Crop Management Zones (Desert Southwest = 23, 33, 34, 43; Southern High Plains = 5, 15, 19; South Texas = 37.1, 38.1, 41, 44, 57, 58; Central Rolling Plains = 40, 48; Lower Mississippi Valley = 37, 38; Upper Mississippi Valley = 17, 42; Central Coastal Plain = 69; Tennessee Valley = 63; Eastern Coastal Plain = 67; Southern Piedmont = 66).

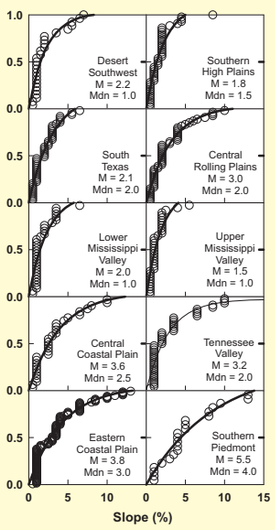


Figure 1. Cumulative frequency of counties within a region with increasing slope. (M = mean slope; Mdn = median slope)

Box 1. Relationship of soil organic C with SCI.

Southeastern USA
$SOC = 0.25 \pm 0.04$ Mg C ha^{-1} yr^{-1} SCI^{-1}
Franzluebbers et al. (2010) *Plant and Soil* doi: 10.1007/s11104-010-0315-9

Midwest USA
$SOC = 0.35 \pm 0.06$ Mg C ha^{-1} yr^{-1} SCI^{-1}
Franzluebbers et al. (2010) *Journal of Soil and Water Conservation* (accepted 13 May 2010)

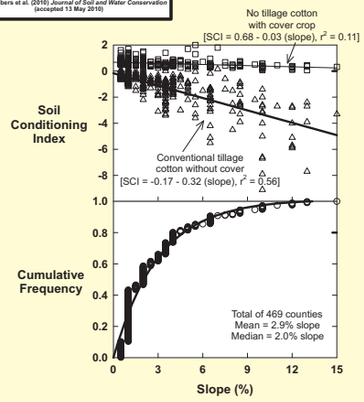


Figure 2. (Upper): Soil conditioning index as affected by slope and cropping system. (Lower): Cumulative frequency of counties with increasing slope.

Table 2
Soil conditioning index value s estimated for each of seven management systems in 10 regions of the Cotton Belt. One observation was made for each county represented in each region.

Management System	Desert Southwest	Southern High Plains	South Texas	Central Rolling Plains	Lower Mississippi Valley	Upper Mississippi Valley	Central Coastal Plain	Tennessee Valley	Eastern Coastal Plain	Southern Piedmont	All regions
	Region of Cotton Belt										
CT1 – cotton	-0.01	-0.25	-0.83	-0.69	-1.77	-0.99	-1.59	-2.03	-1.15	-1.96	-1.13
NT1 – cotton	0.80	0.60	0.38	0.47	0.23	0.36	0.20	0.26	0.27	0.22	0.38
NT2 – cotton with cover	1.32	0.87	0.61	0.70	0.46	0.55	0.40	0.50	0.45	0.47	0.63
NT3 – cotton-cotton-peanut-corn with cover	1.34	0.88	0.55	0.67	0.30	0.47	0.24	0.32	0.35	0.28	0.54
NT4 - cotton-corn-wheat/soybean with cover	1.18	0.80	0.51	0.63	0.26	0.44	0.19	0.29	0.30	0.24	0.48
NT5 – cotton-cotton-clover/grass hay-grass pasture-corn with cover	1.25	0.87	0.65	0.72	0.53	0.60	0.46	0.55	0.50	0.53	0.67
P1 – Permanent perennial pasture with rotational grazing	1.53	1.27	1.15	1.18	1.03	1.06	0.91	1.01	0.91	0.99	1.10
Contrast	Pr > F										
Conservation vs conventional: (CT1 vs all others)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cropped vs grass: (NT1+2+3+4+5 vs P1)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Monoculture vs rotated cotton: (NT1+2 vs NT3+4+5)	<0.001	<0.001	0.03	0.004	0.88	0.22	0.99	0.90	0.42	0.97	0.003
Cover vs no cover: (NT1 vs NT2)	<0.001	<0.001	<0.001	<0.001	0.16	0.002	0.13	0.12	<0.001	0.21	<0.001
Cotton 1 of 3 yr vs more often: (NT4 vs NT3+5)	0.06	<0.001	0.05	0.09	0.28	0.09	0.15	0.28	0.002	0.32	<0.001
Cotton rotated with peanut vs grass: (NT3 vs NT5)	0.19	0.71	0.06	0.22	0.17	0.05	0.10	0.14	0.002	0.21	<0.001

CT is conventional tillage; NT is no tillage

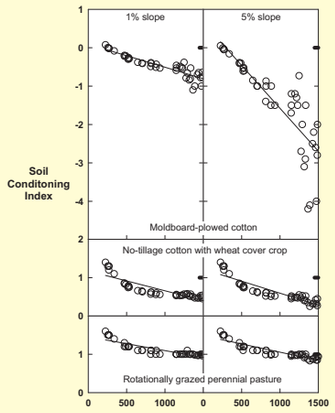


Figure 3. Soil conditioning index as affected by slope, management system, and mean annual precipitation.

Summary and Conclusions

- Regional differences in production characteristics were evident (Table 1).
- Regional differences occurred in typical land slope (Fig. 1).
- Land slope had a large influence on SCI values under conventional tillage, but not under no tillage (Fig. 2).
- SCI values were always lower under conventional tillage cotton than under conservation crop systems (Table 2).
- SCI values were almost always greater with than without cover crop (Table 2).
- Part of the regional differences in SCI was due to climate, in which SCI values decreased with increasing mean annual precipitation (Fig. 3). The effect was greatest when soil was tilled and land had high slope; a response related to greater erosion with greater precipitation.
- Assuming a linear relationship with SCI (Box 1), soil organic C sequestration (Mg C ha^{-1} yr^{-1}) would be:

-0.28 ± 0.18	CT1 (Conventional-tillage continuous cotton)
0.09 ± 0.05	NT1 (No-tillage continuous cotton)
0.16 ± 0.07	NT2 (No-tillage continuous cotton with winter cover crop)
0.14 ± 0.09	NT3 (No-tillage cotton-cotton-peanut-corn rotation with cover crop)
0.12 ± 0.08	NT4 (No-tillage cotton-corn-wheat/soybean rotation with cover crop)
0.17 ± 0.06	NT5 (No-tillage cotton-cotton-clover/grass hay-grass pasture-corn rotation with winter cover crop)
0.28 ± 0.05	P1 (Permanent perennial pasture with rotational grazing)

- Factors affecting SCI (and SOC) were:

Management > Slope > Precipitation > Soil texture