EFFECTS OF TRANSITIONAL CONSERVATION RESERVE PROGRAM LAND MANAGEMENT PRACTICES ON SOIL ORGANIC MATTER

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ABSTRACT

Information was needed regarding changes in soil organic matter and management practices to conserve soil improvement accrued during the Conservation Reserve Program (CRP) upon returning these lands to agronomic production in semiarid regions. We determined the changes in soil carbon (C) in two CRP field soils after three years of intensive grass management and winter wheat production. The study sites were located on Dalhart fine sandy loam (Aridic Haplustalf) and La Casa-Aspermont clay loams (Typic Paleustoll) found near Forgan and Duke, OK, respectively. Management changes from CRP to intensive Old World bluestem (OWB) forage and no-till (NT) wheat production resulted in no overall change in soil total C but led to the stratification and small gains of organic C in the 0-2" soil depth of the Dalhart soil, compared to the OWBUF treatment where OWB forage was removed every year without the benefit of fertilizer applications. In the La Casa-Aspermont soil, only the NT wheat system showed similar organic C gains in the surface 0-2" depth. Otherwise the remaining alternative land management systems did not cause any significant change in soil total and organic C. Using shallow tillage to destroy the OWB sod and prepare crop seedbeds appeared to lower organic C content in the first 2" soil depth of the Dalhart soil, possibly preventing the development of a surface organic matter crust. Therefore, increased intensity of forage management or no-tillage wheat production systems allow land managers of former CRP grasslands to maintain the organic matter status found under the CRP sod in regions of limited rainfall.

INTRODUCTION

There were 1.2 million acres enrolled in the Conservation Reserve Program in Oklahoma after the 12th signup period. Most of this acreage was located in western counties along the Oklahoma-Texas border and was cropped annually to winter wheat and cotton. These lands suffered from moderate to severe soil erosion by wind and water. Old World bluestem (*Bothriochlora ischaemum* L.) and native grasses were extensively used to provide a permanent cover on highly erodible former croplands. The conservation program has been credited with substantial reduction in wind and water erosion of these former croplands (Lindstrom *et al.*, 1998). The program was reauthorized in 1996 adding environmental benefits to the requirements for contract renewal or new enrollment. Landowners must meet stricter environmental benefit criteria for re-enrollment or return these fields to livestock or crop production.

Changing these grasslands back to croplands once again generated substantial concerns that revolved around best-management practices to kill the sod, plant crops, how to best maintain erosion control on these former highly erodible croplands and conserve the benefits accrued under the CRP. A number of cropping studies were conducted across the Great Plains to provide integrated guidelines for tillage, chemical control of CRP grass and weeds, fertility, and crop management (Schuman et al., 1995; Tanaka, 1995; Medlin et al., 1998; Unger, 1999; Dao et al., 2000). A study of tillage treatments on Pullman clay loam indicated that retention or removal of the grass cover slightly affected sorghum and wheat yields (Unger, 1999). Vegetation retention interfered with crop planting and establishment, particularly with NT practices, because of limited planting slot closure in dry soil conditions. Nitrogen fertilization was found to increase wheat yields due to the low fertility status in CRP grassland and the large influx of C upon soil incorporation of the CRP sod (Medlin et al., 1998; Unger, 1999). Dao and co-workers found that removal of the old grass litter and regrowth vigor increased the success of suppressing and killing of the OWB cover and the uniformity of the crop stand. Early growth suppression of the OWB was essential to conserve stored soil water for growing a winter wheat crop in the year a CRP contract expires. Maintaining the CRP cover to support livestock production required annual forage harvest and improved soil fertility management. The intensive management increased forage quality and yields between 49 to 110% and 170 to 400%, respectively.

Another major concern of CRP landowners was how to best conserve the benefits to the soil that accrued during the CRP and sustain the increased production intensity. Soil C increased at an average rate of 980 lb/A/yr at selected CRP sites in the Central and Southern Great Plains (Gebhart *et al.* 1994). However, others have reported little or no change in soil organic C (Schuman *et al.*, 1995). Staben and co-workers (1995) found no significant difference in soil organic C and microbial biomass C between field soils under wheat-fallow and CRP management. Carbon mineralization potentials were 50% higher in the CRP soil than the wheat-fallow soil. Robles and Burke (1998) found minimal differences in total C between soils from CRP fields seeded to wheatgrass (*Agropyron smithii*) and brome (*Bromus inermis*) and wheat-fallow soils. However, the CRP soil had 8.8 lb mineralizable C /A/day or over 2.5 times more than that observed in a wheat-fallow field soil. Returning these highly erodible lands to row crop production may bring back the degraded conditions that made these lands eligible for the CRP in the first place. Observed soil degradation included reduced soil macroporosity and decreased water infiltration within one year of converting CRP grassland to croplands (Lindstrom *et al.*, 1998). Sediment loss was appreciably greater under disk-tillage used to destroy the CRP sod and averaged between 50 to 130 lb/A more than chemically killed sod for no-till wheat production (Gilley *et al.*, 1997). The objective of this study was to determine the changes in organic matter and improve our understanding of the process of soil C accretion from grass and crop residues as affected by land management under semiarid environments.

MATERIALS & METHODS

We conducted the study of transitional CRP systems on two producers' CRP fields. One experimental site was in northwest OK, near the town of Forgan. Annual precipitation averaged 18 in and mean minimum and maximum temperatures were 40 and 70 ^{o}F, respectively. The major soil at the Forgan site was Dalhart fine sandy loam on 1 to 3% slope. The second study site was near the town of Duke, OK. The annual precipitation was approximately 29 in. Annual minimum and maximum temperatures averaged 45 and 75 ^{o}F, respectively. The major soils at the Duke site were La Casa-Aspermont clay loams with a 1 to 3% slope. Selected soil properties are presented in Table 1. The old OWB growth in a 25-a block of the CRP fields was removed to establish four land management treatments in 1994. At Forgan, four replicated plots measuring 150 by 300 ft were established to evaluate: (i) OWBUF = minimum OWB management (no fertilizer added following the removal of the old biomass), (ii) OWBF = optimal grass management (fertilizer added following the removal of the old biomass), (iii) CT = conventional-tillage (i.e., sweep-tillage (ST)) conversion to wheat, and (iv) NT = no-till conversion to wheat. At Duke, field plots were established to evaluate the same four management systems, except that disk-tillage (DT) was used to destroy the sod before tillage and planting. The ST, DT, and NT plots were re-established after wheat harvest for the next three years. Soil samples were collected from both locations before grass mowing or burning of the old litter and before tillage/no-till operations in the cropped treatments. Soil cores were taken to 12" and separated into 0-2", 2-4", 4-8", and 8-12"samples using a 3" I.D. soil core sampler. Total sample weights and water content were measured to calculate soil bulk density. Samples were composited and split into halves; a set of soil samples was refrigerated at 40 ^{o}F for biological measurements. The remainder was air-dried, crushed and sieved to pass a sieve with 2-mm openings, and stored at room temperature until chemical analysis. Total soil C and organic C were determined before and after acid washing of the soil samples by dry combustion (Nelson and Sommers, 1996). One-g samples were weighed into ceramic boats and oxidized at 1400^{o}C to determine C concentrations using a CNS-2000 (LECO Corp., St Joseph, MI)[1]. To remove carbonate-C from another set of all soil samples, a 1*M* HCl solution was added incrementally to 5 g of soil until effervescence ceased. The sample was left standing overnight with an additional 25 mL of a 1*M* HCl solution. The supernatant was decanted and the residue was rewashed with deionized water until the supernatant pH was near neutral. The soil residue was subsequently dried and total C was determined as described above. Final C concentrations were adjusted for the weight loss due to carbonate removal.

At each location, the four management treatments were established with four replications based on a randomized complete block design. Triplicate subsamples of soils from each management plot were analyzed as described above for C. Significant differences in treatment means were detected following analysis of variance and a multiple range test at the 0.05 level of probability.

RESULTS AND DISCUSSION

A great deal of spatial variability existed in total C with soil depth at both field sites (Table 2). Both the Dalhart and La Casa-Aspermont soils had varying levels of free carbonate-C within the Ap horizon to account for the high variability in soil total C. The variations in both C fractions were high within 4 to 12" from the soil surface. The spatial variability made some treatment comparison difficult to resolve the effects of management on soil total C. For example, as management system x depth interactions were not statistically significant, total C means showed that OWBF, CT and NT treatments did not appear to have alter soil total C in the Dalhart soil, compared to the OWBUF treatment of continuing the CRP cover with annual forage harvest as the only management input (Table 3). Yet, the CT treatment had lower relative total C concentrations than the OWBUF, OWBF, and NT treatments, at all four depths. The total C

[1] The mention of a trade or manufacturer names is made for information only and does not imply an endorsement, recommendation, or exclusion by the USDA-ARS.

decrease in the 0-2” depth was not statistically significant but was corroborated by the low organic C in the same soil depth. The organic C results were contrary to the trend toward C stratification and surface gains in the other land management systems. Shallow tillage may have caused soil mixing and would prevent the formation of an organic C crust observed in the OWB and NT systems and thus resulted in low C concentrations at the CT soil surface of the Dalhart soil.

In the La Casa-Aspermont soil, the OWBF, CT, and NT treatments did not significantly alter soil total C any more than the OWBUF treatment did, at least in the 0-4” soil depth (Table 3). Total C distribution with depth in the La Casa-Aspermont soil was highly variable across the CRP field (Table 2). Close examination of the NT treatment revealed that low relative total C concentrations occurred in the 4 to 12” depths. It was concluded that these NT plots did not have high levels of free carbonate-C at these depths and that the low total C relative concentrations were not the results of deep C loss processes since no deep mechanical disturbance was introduced in this management system. Calculations yielded low relative concentration values when the NT total C concentrations were normalized against the high concentrations found in the OWBUF treatment.

The undisturbed conditions in the OWBF and NT systems resulted in the layered distribution of organic C with depth. There were small net gains in the surface 2” of the OWBF and NT treatments and the 2 and 4” depth of the OWBF treatment in the Dalhart soil, compared to the OWBUF treatment. The NT wheat system was the only system to show increased organic C in the surface 2” depth of the La Casa-Aspermont soil. Partially incorporated plant debris formed an organic crust to raise organic C concentrations of the 0-2” layer (McConnel and Quinn, 1988). Had we not done a shallow sampling of the soil, this small accumulation of C would have been diluted and gone undetected. Changes in soil total or organic C content remain hard to detect, particularly in the short timeframe since land use conversion. Changes in soil biological and biochemical properties may be more apparent, given the higher management intensity of cropping systems and soil perturbations that affect biological activities in the near-surface and root zones (Robles and Burke, 1998; T. H. Dao et al., unpublished data).

In summary, the re-vegetation of highly erodible Dalhart and La Casa-Aspermont soils to perennial warm-season OWB grasses may have reduced the erosion of these fragile soils. Given the heterogeneity of total and organic C concentrations in these eroded fields, intensive OWB forage and NT annual wheat production appeared to have maintained the C status found during the CRP. The challenge for land managers will be to sustain the C-rich environment that existed during the program, maintain the status quo in soil C levels coming out of the CRP, and possibly promote the development of surface organic crust and accumulation of organic C in highly erodible soils in regions of limited rainfall.

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INTERPRETIVE SUMMARY

Large-scale re-vegetation efforts to promote soil conservation and support farm income under the Conservation Reserve program (CRP) was beneficial to air and water quality by controlling soil erosion on highly erodible croplands across the U.S. To CRP landowners faced with expired contracts, alternate land use options include forage-livestock production or killing the grass cover and conversion back to row crop production. However, changes in soil organic matter and integrated management systems to conserve soil improvement accumulated during the CRP upon converting back to forage and crop production in semiarid regions are not well understood. After three years, management changes from CRP to intensive OWB forage and NT wheat production resulted in no overall change in soil total carbon content and may have led to small gain in organic matter at the very surface of the soil, compared to the OWBUF treatment, where OWB forage was harvested every year without the benefit of fertilizer applications. Using tillage to incorporate the OWB sod and prepare clean seedbeds resulted in lower soil organic matter in the first 2” soil depth by ruling out the formation of a surface organic crust. In the short term, increasing the intensity of grass management or no-tillage production systems appeared to allow former CRP land managers to control erosion and maintain the organic matter status found under the CRP sod in regions of limited rainfall.

Table 1: Selected properties of the Dalhart and La Casa-Aspermont soils

Series Name	Particle-size analysis			pH (0.01 *M* $CaCl_2$)	Organic C	Organic N
	sand	silt	Clay			
	%	%	%		%	%
Dalhart	61	25	14	6.6	0.52	0.06
La Casa-Aspermont	30	57	13	7.7	1.41	0.13

Table 2: Soil C and N in CRP fields under an OWB sod before the establishment of land management treatments in 1994

Series Name	Depth	Total C	Organic C	Organic N
	Inch	lb/ft^3	lb/ft^3	lb/ft^3
Dalhart	0 – 2	0.42 ± 0.07 †	0.40 ± 0.06	0.04 ± 0.01
	2 – 4	0.34 ± 0.07	0.34 ± 0.06	0.03 ± 0.01
	4 – 8	0.44 ± 0.11	0.45 ± 0.11	0.04 ± 0.01
	8 – 12	0.46 ± 0.09	0.45 ± 0.07	0.05 ± 0.01
La Casa-Aspermont	0 – 2	1.23 ± 0.24	0.96 ± 0.14	0.10 ± 0.02
	2 – 4	1.01 ± 0.18	0.80 ± 0.09	0.08 ± 0.01
	4 – 8	1.19 ± 0.28	0.93 ± 0.14	0.08 ± 0.01
	8 – 12	1.28 ± 0.45	0.84 ± 0.12	0.08 ± 0.01

† Means and standard deviation (n = 12)

Table 3: Effects of land management change from minimum-input Old World bluestem production to intensive forage and wheat production on selected C pools of the Dalhart and La Casa-Aspermont soils in 1997.

Land management system	Depth	Dalhart fine sandy loam			La Casa-Aspermont clay loam		
		Total C	Total C system means‡	Organic C	Total C	Total C system means	Organic C
	Inch	%		%	%		%
OWBUF	0 – 2	100 †		100	100		100
	2 – 4	100		100	100		100
	4 – 8	100		100	100		100
	8 – 12	100	100 a	100	100	100 a	100
OWBF	0 – 2	112		137	110		107
	2 – 4	105		131	100		84
	4 – 8	93		113	86		99
	8 – 12	86	96 a	78	84	92 a	112
CT	0 – 2	69		72	96		106
	2 – 4	86		112	108		91
	4 – 8	88		117	97		103
	8 – 12	90	82 a	65	86	95 a	96
NT	0 – 2	100		137	99		121
	2 – 4	84		108	88		82
	4 – 8	89		112	60		91
	8 – 12	111	95 a	74	55	75 a	105
	$LSD_{0.05}$			18§			15§

† Expressed as fraction of the C concentrations occurring at the same depth of the OWBUF treatment in 1997. (OWBUF = Old World bluestem-unfertilized; OWBF = Old World bluestem-fertilized; CT = Conservation tillage wheat; NT = No-till wheat).
‡ Treatment means followed by same letter are not significantly different at the 0.05 level of probability.
§ Significant land management system by depth interactions.