CARBON BUDGET IN DRYLAND AGROECOSYSTEMS AFTER 12 YEARS IN NO-TILL AS AFFECTED BY CLIMATE GRADIENT, SLOPE POSITION, AND CROPPING INTENSITY

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ABSTRACT

Because available soil water is the most limiting factor in dryland cropping systems in the central Great Plains, summer fallow was implemented to stabilize production by storing two years of soil water for one year's crop. The traditional dryland cropping system consists of conventional tillage management of a crop-fallow rotation which produced one crop every two years. In order for the fallow period to successfully store soil water, weeds and volunteer plants need to be controlled by tillage. However, excessive tillage and summer fallow has enhanced organic matter oxidation and added to atmospheric CO_2 emissions. By implementing no-till management, a reduction in the frequency of summer fallowing is feasible, and the cropping intensity is increased. Whether soils are a source or sink for C depends on the net balance between inputs and outputs. The objectives of this research were to quantify a simple carbon budget after 12 years of no-till management and to determine what the percentage of inputs are accounted for based on climate, slope position, and cropping intensity. Each cropping system was evaluated across a catenary sequence of summit, sideslope, and toeslope positions at three site locations within a 420 mm precipitation zone. Sites located near Sterling, Stratton, and Walsh, Colorado represents an evaporation gradient with Sterling having the lowest evaporation, and Walsh the highest. Cropping systems included wheat (Triticum sestivum)-fallow (WF), wheat-corn (Zea mays)-fallow (WCF), wheat-corn-millet (Panicum miliaceum)-fallow (WCMF), and continuous cropping without summer fallow (CC). When depths were summed to 10 cm, the CC cropping system had significantly more soil organic C (SOC) than WF without any interactions with site or slope. Surface residue C was significantly lower in the WF cropping system than in the WCF, WCMF, and CC systems. Percent C additions accounted for by the change in SOC and in the surface residues at the end of the 12 year period were lower at the high potential evapotranspiration (PET) site than at the medium and low sites, were lower on the toeslope soils than on the summit soils, and were lowest in the WF system. Of the C recovered after 12 years in no-till management, 2/3 was in above ground surface residues and 1/3 was due to increased SOC.

INTRODUCTION

In the past decades, conservation tillage and no-till have significantly lowered the rates of SOC loss. In the Great Plains region, no-till management systems also have allowed for more intensive cropping than the historical crop-fallow system, and in recent years increased intensity of cropping has become more common in the Great Plains. Improving water use efficiency by managing the length and time of fallow, coupled with the lack or reduction of tillage has allowed for the intensification of cropping systems in the Great Plains. Conservation tillage and no-till management in the past decades has significantly lowered the rates of soil organic C loss. Changes in the levels of crop production in this region has had a direct effect on the levels of SOC (Sherrod et al., 2003). Estimates of the amount of change over a given period of time and efficiency of conversion of the crop residue inputs into the SOC pool are needed to assess the level of impact a particular management has. The objectives of this study were to evaluate the effects of no-till cropping systems on C dynamics over 12 years at three sites in eastern Colorado, and to determine if climate (PET gradient) and/or slope position modifies these changes.

MATERIALS AND METHODS

This study was conducted within a long-term sustainable dryland agroecosystems management project initiated in the fall of 1985. This sub-study combines four major variables, each with a gradient, which consist of 1) PET location, 2) soil productivity level (slope position), 3) cropping intensity, and 4) time. Sites are located in eastern Colorado along a north to south gradient of increasing potential evapotranspiration (PET) within a 100 year average annual precipitation of 420 mm. The soil variable is represented by slope positions of summit, side, and toeslope positions along a catenary sequence across which cropping system treatments were imposed. Cropping systems include two complete replications of wheat-fallow (WF), wheat-corn-fallow (WCF), wheat-corn-millet-fallow (WCMF), and continuous cropping (CC) which included corn/sorghum, wheat, hay millet and sunflower in order of frequency. Grain sorghum [*Sorghum bicolor* (L.) Moench] replaces corn in the cropping systems at Walsh (Peterson et al., 1993).

Annual straw to grain ratio samples were taken for each crop at each site and slope position by sampling 1 meter row of above ground biomass prior to harvest for drilled crops and by sampling 10 plants for row crops. Stover yields were added up for each cropping system within each site and slope position and the total cumulative yield then multiplied by 0.45% (the estimate of the average amount of C) to obtain total above ground stover C input after 12 years.

Final surface residue samples at the end of 12 years were collected in each cropping system in 1997 at each location and slope position. A quadrangle of 0.50 square meter was used to take two samples from within each experimental unit. Care was taken to not "dig up" any residue that was partially covered. Samples were oven-dried, weighed and finely ground. Ground samples were then analyzed for total C by dry combustion using a LECO CHN-1000. Residue yields were then multiplied by the percent C found to obtain residue C found on the soil surface after 12 years.

Soil cores were taken in both 1986 and 1997 from all cropping systems at all three sites and at all three slopes from 0-2.5, 2.5-5, and 5-10cm depth increments for each of the two replications. A total of fifteen 2.54 cm diameter soil cores were obtained and composited for each depth in each plot with surface residue excluded from the samples. Soils were air dried for several days and then ground to pass a 2 mm sieve size. All visible plant material larger than 2mm sieve size were removed. A 1.00 g sub-sample from this 2mm sieved soil was analyzed for SOC by wet oxidation using the Walkley-Black titration method (Nelson and Sommers, 1982). The change in SOC was therefore the final SOC in 1997 minus the initial SOC from 1986.

RESULTS AND DISCUSSION

Changes in SOC were significantly influenced by cropping system (P=0.0069, Figure 1). As cropping intensity increased so did the change in SOC with the CC having significantly higher levels than WF and WCF. Only the WF system showed a negative change in SOC with a loss of 410 kg ha^{-1} over the 12 year period. Cumulative stover C additions were strongly influenced by cropping systems ($P < 0.0001$). The CC cropping system had the highest stover C additions followed by WCMF and WCF with WF having the lowest levels (Figure 2). Surface residue C in 1997 was also strongly influenced by cropping systems ($P <.0001$, Figure 3). The WF cropping system had the lowest levels of residue C than found in the WCF, WCMF, and CC systems averaged across PET sites. Surface residue C levels found at the end of the 12 years when averaged over sites and slopes was 640, 1800, 1745, and 1660 kg ha^{-1} for the WF, WCF, WCMF, and CC cropping systems respectively. In comparison, the change in SOC levels when averaged across sites and slopes was -410, 452, 890 and 1860 for WF, WCF, WCMF, and CC respectively. The magnitude of the impact of the residue C levels on the C budget is notable in that they are, on average across sites, slopes and cropping systems, approximately 2 times the levels found in the change in SOC for the 0-10 cm depth. This demonstrates the need to account for the amount of C sequestered in the surface residue when looking at SOC changes in no-till management systems.

The amount of stover C additions over 12 years that is accounted for in the surface 10 cm of soil plus the surface residue C is defined as %C recovered. Cropping system independently influenced the % C recovered as demonstrated by the lack of significant interactions ($P = 0.0068$). As cropping intensity increased so did the %C recovered, with WF recovering significantly less (<5%) than did WCF, WCMF, and CC (Figure 4). Slope position also influenced the % C recovered, with the toeslopes having approximately half of the levels found in the summit and sideslope soils (Figure 5). Decomposition rates are apparently approximately twice as high in these depositional soils, likely due to the increase in available water. Sites showed a trend towards influencing the levels of % C recovered ($P= 0.0740$), with mean values of 29.5, 12.3, and 6.7 % for the low, medium and high PET sites respectively (Figure 6). This trend was expected, as it is assumed that the cooler climates will sequester more of the C inputs than the warmer climates due to lower oxidation rates.

CONCLUSIONS

Organic matter oxidation rates were impacted by climate gradient, slope position and cropping intensity in the 0-10 cm soil depth after 12 years under no-till management. The benefits of cropping intensity on increased C levels were due largely to the introduction of a corn/sorghum crop in the rotation and to a lesser degree due to the increases due to cropping intensity. The increase in C after 12 years was partitioned with two thirds in above ground residues and one third in increased SOC. Although surface residues are not sequestered in a stable pool, they are nonetheless an important C stock which represents the first step in becoming SOC that should be accounted for when evaluating management effects on SOC changes.

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Figure 1. Soil organic C change after 12 years under no-till management by cropping system.

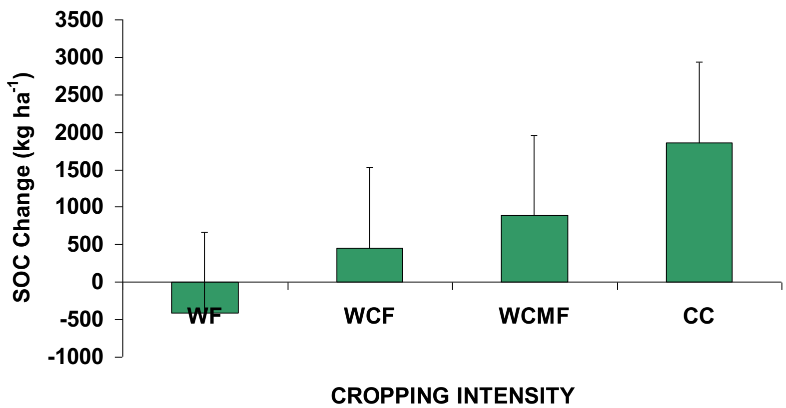
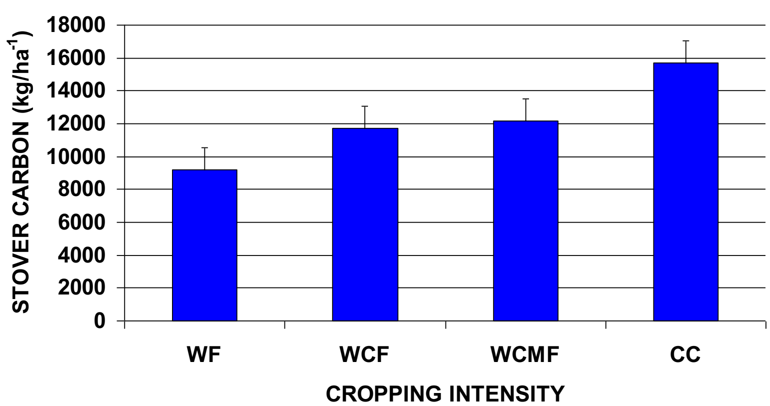


Figure 2. Cumulative stover C inputs by cropping system after 12 years under no-till management averaged over PET sites and slope positions.



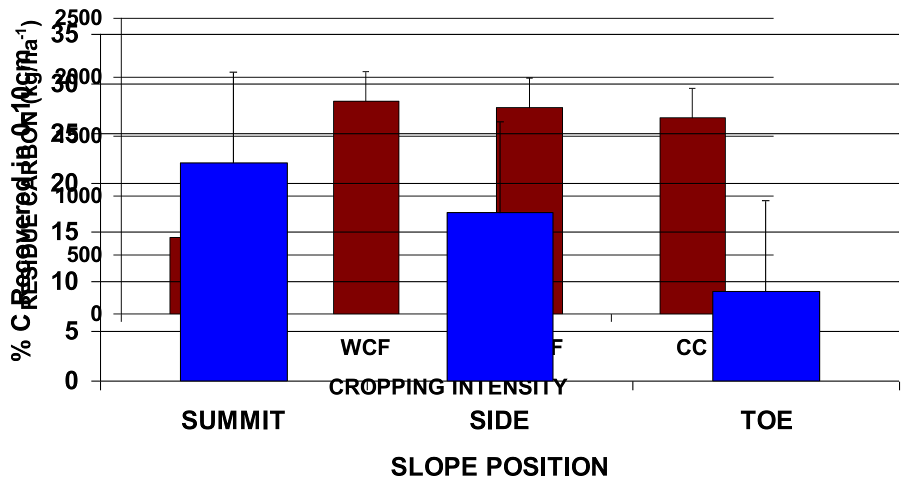


Figure 3. Surface residue C after 12 years under no-till management by cropping system.

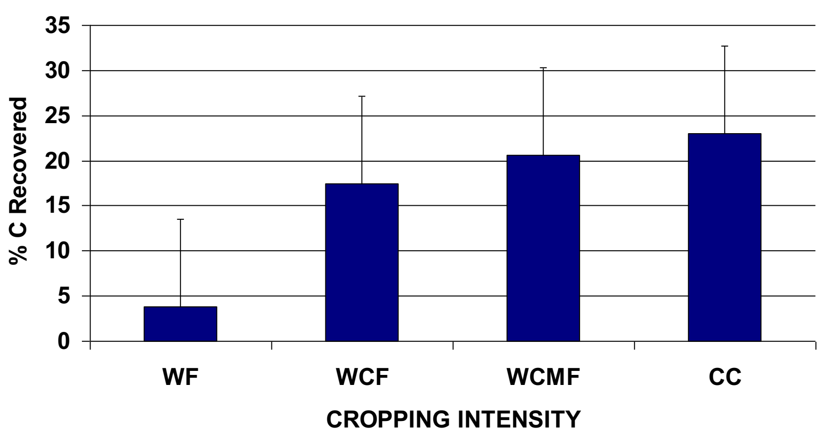


Figure 4. Percent C recovered after 12 years under no-till management by cropping system.

Figure 5. Percent C recovered after 12 years under no-till management by slope position averaged across PET sites and cropping systems.

Figure 6. Percent C recovered after 12 years by PET location averaged over slopes and cropping systems.