Building soil carbon content of Texas Vertisols

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Abstract
Soils in central Texas, USA (Udic and Entic Pellusterts) have been degraded by intensive agricultural practices. This was typified by loss of soil organic carbon from about 1880 to 1949 from a concentration of about 6.5% in the surface to about 1%. Agriculture practices since 1949 are slowly rebuilding the soil carbon content. Recent research has shown that modern conventional practices have increased soil organic carbon sequestration at a rate of 0.15 Mg C/ha/yr. Intensive management practices such as no-tillage increase this rate an additional 0.3 Mg C/ha/yr. Conversion from row cropping to perennial grass production increases sequestration to 0.45 Mg C/ha/yr. Several management options are available to sequester carbon in central Texas soils.

Key Words
Tillage, grass establishment, no-till

Introduction
Blackland soils in central Texas, USA consist primarily of 4.5 million hectares of Vertisols (Udic and Entic Pellusterts) (Puentes *et al.* 1988). These deep and dark colored soils were the basis for much of Texas early agriculture. Also, many of Texas major cities have developed in the Blackland region. The central Texas region was used for free range cattle grazing for the most part until about 1875 when the railroads began to extend into the region. Cotton (*Gossypium hirsutum)* production increased greatly at that time and, by 1909, almost 1/3 of the cotton in the world was being produced in this area (Paddock, 1911). Other common crops at that time included corn *(Zea mays)* and hay. By the 1920s more than 70% of the Blackland Vertisols were tilled to produce crops, using the inversion tillage practices common at that time (US Department of Agriculture 1993). Early tillage practices in this region were intensive and involved moldboard plowing as the primary practice to breakout the field from the original prairie vegetation. The fields were commonly tilled eight to ten times during the growing season to prepare the seed bed and to control weeds. A typical management schedule included moldboard plowing, several passes with a disk, harrow, plant, and three or more cultivations before harvest. In retrospect, a benefit of intensive tillage was to oxidize organic matter in the soil and thus release plant nutrients for the growing crop. By the early 1940s, a common rotation was two years of cotton and three years of small grain (Richardson 1993). Cotton produces small amounts of residue returned to the soil to replenish the organic carbon oxidized by the agricultural practices of the time. As a result of the agricultural practices commonly used at that time and the choice of crops, tilled soils were severely depleted of organic carbon compared to the native prairie in 1949.

Modern agricultural practices have changed greatly from the past and have produced changes in soil carbon content. About 80% of the Blackland Vertisols are in farms and ranches. Of that amount, about half are planted to croplands and the rest predominately are improved pasture. Wheat *(Triticum aestivum L.),* oat *(Avena sativa),* grain sorghum *(Sorghum bicolor*), corn *(Zea mays)* and cotton (*Gossypium hirsutum)* are the major crops in the region at present. Only very small amounts of native grassland still exist. An opportunity to compare soil properties with a known starting condition was discovered recently by the USDA-ARS Grassland Soil and Water Research Laboratory for a study area near Riesel, Texas. In 1949, a series of soil samples were taken from five fields at the GSWRL-Riesel site (Baird, 1950). The samples were oven dried and placed in labeled cartons and stored in a dry location for over 55 years. The management history of these fields was recorded for most of the intervening years. The goal of the original study was to determine the effect of cropping on soil water storage. In 2004, these fields were sampled again. The objective of the current study was to compare soil properties between the management regimes and between the two sampling periods. This report deals with the soil organic carbon content comparisons of the archived and modern soil samples. Results will be compared to other recent findings for selected management practices.

Methods
Soil samples were taken to a depth greater than 90 cm with a hand auger in 1949 and hydraulic core tubes in recent studies. Cores were divided into sections representing depth increments of 0 to 5, 5 to 10, 10 to 15, 15 to 20, 20 to 30, 30 to 60, 60 to 90, and 90 to 120 cm depth. Soil water content was determined on an aliquot

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and bulk densities were determined for modern samples. The remainder of the segment was gently crumbled, passed through a 2mm sieve and air dried. For all samplings, plant stem and root segments were hand picked from the soil samples. The samples were ground in a ball mill to pass through a 250-µm sieve and then stored at room temperature in glass bottles. A sample aliquot (approximately 1 g) was analyzed for organic carbon with a Leco CR412 Carbon Determinator (Leco Corp, Augusta, GA, USA) using the combustion method of Chichester and Chaison (1992). While carbonates were present in the soils, this method of analysis differentiates between organic and inorganic carbon by burning the organic carbon at a temperature of 500 ºC that leaves the inorganic carbon relatively intact. The inorganic carbon was later determined by burning at 1050 ºC to obtain the total carbon and subtracting the amount of organic carbon. Carbon mass in the segment was determined by calculating the amount of carbon in a depth increment by multiplying the carbon concentration by the bulk density. Statistical analysis was conducted using t-tests to determine differences in soil carbon content.

Results
The soils studied in this project are located near Riesel and Temple in central Texas, USA. Mean annual temperature is 19.5 °C and average rainfall ranges from 840 to 908 mm/yr. Soils in all fields are Vertisols (Udic Pellusterts) (Soil Survey Division Staff 1993).

A concern with this study was the possibility that some of the archived samples soil organic carbon had been lost while in storage. The results from the native prairie sites were from both sampling periods were compared to see if differences occurred with similar management. Soil organic carbon concentration was significantly greater in the surface 15 cm for the 2004 sampling period than in the 1949 sampling period, 2.77 percent in 1949 and 3.31 percent in 2004. However, mean differences in concentration between the two sampling periods were not significantly different for depths greater than 15 cm. Prior to 1949, the native prairie site had been grazed for an extended period of time.

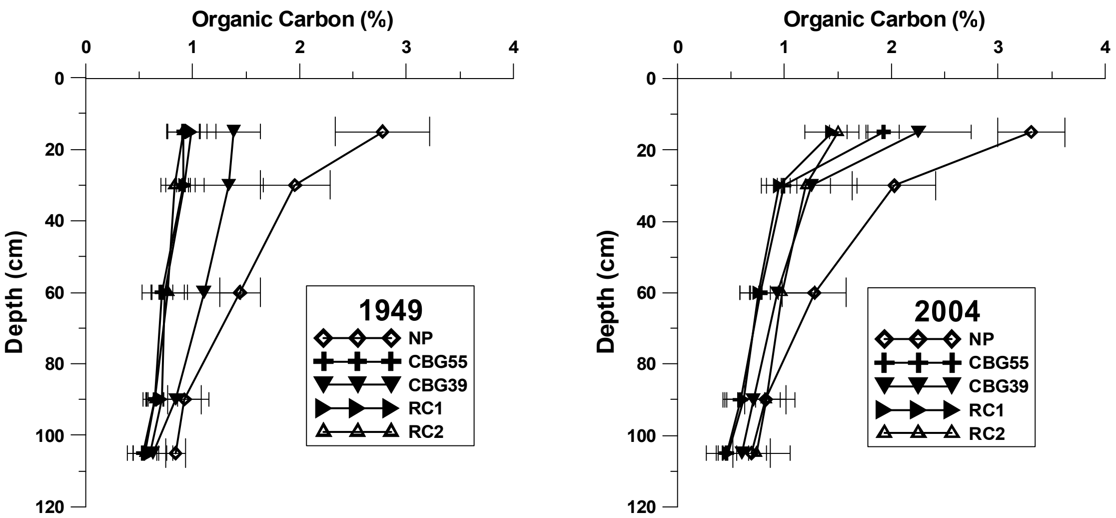

Figure 1. Comparisons of soil organic carbon profiles from 1949 and 2004 samples for selected management practices. NP is Native Prairie, CBG is Coastal Bermuda Grass, and RC is Row Crop. Error bars represent ± one standard deviation. (From Potter 2006).

Compared to native grasslands, the soil organic carbon was greatly depleted by agricultural practices prior to 1949. Soil organic carbon concentrations in the tilled fields were greatly reduced compared to that found in the Native Prairie (Figure 1). T-tests comparing the organic carbon concentration of NP to the other soils revealed significant differences ($P<0.05$) in concentration to a depth of at least 90 cm. Organic carbon concentration had been reduced throughout the profile to a depth of 90 cm by early agricultural practices. The mean organic carbon concentration in the 1949 soil samples was similar throughout the profile with a mean concentration of about 1%.

Differences in soil organic carbon between the 1949 samples and the 2004 samples are a result of management and weather effects. In the 1949 time frame, farming practices changed dramatically. One major change was the increased use of fertilizers (US Department of Agriculture 1993). At the same time, plant populations also increased dramatically with the improvement of crop varieties. Cotton production was greatly reduced on the site. This has resulted in a large increase in the amount of residue being returned to the soil, which in turn replenished some of the organic matter being oxidized.

Soils in the two fields with nearly continuous crop production (RC1 and RC2) differed slightly in the soil organic carbon profiles between sampling periods. Predominant crops during this period included corn, wheat and grain sorghum. Soils in field RC1 were very similar to the soils in the 1949 sampling, with the exception of a significant increase in carbon concentration from 0 to 15 cm in 2004. Soils in RC2 from the 2004 sampling period also had a larger organic carbon concentration in the surface soils, which extended to 30 cm in this field. Below 30 cm, carbon concentrations were similar in 1949 and 2004. Estimating the amount of C sequestered by modern farming methods using the difference between the 2004 samples and 1949 samples, soils in field RC1 sequestered 8.7 Mg C/ha (158 kg C/ha/yr) and soils in field RC2 sequestered 6.9 Mg C/ha (125 kg C/ha /yr) in the surface 30 cm during the 55 year time interval.

It should be noted that the change in soil carbon concentration found in this study is without the use of no-tillage management practices. In a study comparing no-till with conventional chisel plow management, after 10-yrs continuous management additional differences in soil organic carbon concentration were found in the surface 20 cm of soil (Table 1) (Potter *et al.* 1998). After a corn crop, differences in organic carbon concentration were greatest in the surface 4 cm. No-till resulted in an annual increase in soil carbon of 0.3 Mg C/ha/yr greater than that found in a chisel plow conventional tillage soil.

Table 1. Carbon sequestration rates for Vertisols in central Texas with selected management practices.

Management	Sequestration rate Mg C/ha/yr	Information source
Conventional till	0.12	Potter 2006
No-till	0.30	Potter *et al.* 1998
Perennial grass	0.45	Potter *et al.* 1999

The soil in the two fields that had been planted to perennial Coastal Bermuda Grass (*Cynodon dactylon* (L.) Pers.) for 55 and 39 years, showed similar trends with an increase in soil organic carbon near the surface. Below 60 cm the differences between the 1949 and 2004 samples were not significantly different for these two fields. Restoring the soils to perennial grass vegetation replenished the carbon concentration in the surface.

The estimated amount of carbon sequestered depends on the amount of carbon stored in the soil at the start of the study. To calculate the amount of carbon stored in the soil by taking the difference between the mean 2004 soil carbon and the mean 1949 soil carbon, It was assumed that the soil bulk densities were the same in both sampling periods. Soils in the 39-year grass field sequestered 13.5 Mg/ha C in the surface 30 cm, while in the 55-year grass field, soils sequestered 19.7 Mg C/ha in the surface 30 cm. If, however, the 1949 samples had greater bulk density values than the 2004 samples, then the estimated amounts of carbon sequestered would be less. If the 1949 bulk density values were lower, then estimated amounts of carbon sequestered would be greater. Without measured values, it is difficult to be certain of the 1949 bulk density values. Larger soil organic matter content in 2004 would tend to reduce bulk density in the recent samples. Conversely, the lighter equipment used in 1949 may have resulted in lower bulk density when the archived soils were sampled. Given the assumption of similar bulk density values, carbon sequestration appears to increase throughout the time that grass is grown which agrees with previous work (Potter *et al.* 1999). On similar soils, grass established for periods from 6 to 60 years sequestered carbon in a linear fashion and at a mean rate of 0.45 Mg C/ha/yr (Figure 2) (Potter *et al.* 1999).

Conclusion

Soils in central Texas were degraded during the first 70 years of cultivation. This is illustrated by the loss of soil organic carbon. In the last 60 years changes in crops, fertilization and management practices has resulted in a slow rebuilding of the soil organic carbon in the soil profile. Use of no-tillage and conversion to

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perennial grass accelerates the accumulation of soil carbon.

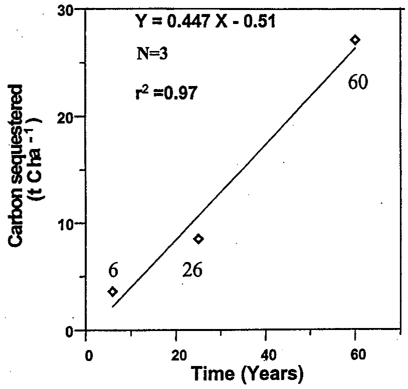

Figure 2. Carbon sequestered in soil after periods of 6, 26, and 60 years of grass establishment after extensive periods of cultivation (from Potter *et al.* 1999).

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