EFFECT OF TILLAGE INTENSITY ON CARBON STOCKS UNDER A SOYBEAN BASED CROP ROTATION IN THE BRAZILIAN CERRADO

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Introduction

Studies performed in North America and the southern region of Brazil indicate that the adoption of zero tillage (ZT) management conserves soil organic matter (SOM) stocks and in regions where conventional tillage (CT) has been practised for many years, SOM stocks often increase. Several factors favour SOM accumulation under such conservation tillage regimes, including high crop yields with large crop above- and below-ground residue inputs (Lal, 1997). Studies performed in the southern region of Brazil suggest that owing to the high export of N in soybean grain, cropping systems managed under ZT which contain soybean as the only legume in the rotation do not present overall positive N balances (Alves et al., 2002) and that such systems accumulate little SOM (Machado e Silva, 2001). Where a winter green manure legume was included in the rotations under the same conditions there were large increases in soil C stocks compared to under CT (Sisti et al., 2003).

In the Cerrado (central savanna) region of Brazil the long dry season (April to October) usually makes it impossible to include any legume other than soybean and, while the consensus appears to be that ZT will conserve soil C stocks better than CT management, very few long-term studies have been conducted to confirm this. In this poster we present the results of a long-term study (19 years) on SOM stocks conducted in the Cerrado region near Brasilia where the same cropping sequence was managed under ZT or four different ploughing regimes.

Materials and methods

The experiment was established in uniform area (10,000 m^2) of native Cerrado vegetation at the experimental farm of the Embrapa Cerrado research centre (Planaltina, Distrito Federal - 15° 35'S, 47° 42'W, altitude 1007 m above sea level) in 1979 on an clayey Oxisol (Typic Haplustox). After removing the Cerrado vegetation the area was divided into two equal parts and potassium chloride fertiliser (171 kg K ha^{-1}) were incorporated in one area with a mouldboard plough (MP) and in the other with a disc plough (DP). The sequence of cultures in the entire experiment was identical and is displayed in Table 1. In each area three treatments were established in areas of 1250 m^2 each: ZT zero tillage for all crops, T1 – tillage to prepare the land for the main summer crop, T2 tillage to prepare the land for the summer crop and after the cropping season a further tillage operation to incorporate the crop residues at the beginning of the dry season. In the MP area all tillage operations were performed with a mouldboard plough and in the DP area using a disc plough. Hence, there were six treatments MPZT, MPT1, MPT2, DPZT, DPT1 and DPT2, and the only difference between MPZT and DPZT was that before the planting of the first crop in 1979, the soil had prepared with a mouldboard plough rather than a disc plough, respectively. The sequence of crops used in the experiment is displayed in Table 1.

Soil samples were taken in October 1999 at depth intervals of 0-5, 5-10, 10-20, 20-30, 30-40, 40-60, 60-80 and 80-100 cm (6 sub-samples) with a Dutch Auger at three points in each plot and in an area of undisturbed native Cerrado vegetation some 120 m from the plots. Soil bulk density was determined in the soils laboratory of the Embrapa Cerrados Centre.

The silt+clay content of all soil samples was determined by wet sieving. For analyses of total C, N and ^{13}C abundance, finely-ground aliquots (1.0 g) of these samples were analysed for total N content using semi-micro Kjeldahl digestion using a Tecator Kjeltec model 3100 (Tecator, Höganäs, Sweden)

Table 1. Sequence of crops planted in each year in all tillage treatments.

Year	Crop	Year	Crop	Year	Crop
1979/80	Rice	1986/87	Soybean	1993/94	Soybean and maize
1980/81	Rice	1987/88	Soybean	1994/95	Rice
1981/82	Soybean	1988/89	Soybean and maize	1995/96	Soybean
1982/83	Pigeon pea	1989/90	Fallow	1996/97	Maize
1983/84	Fallow	1990/91	Maize	1997/98	Soybean
1984/85	Fallow	1991/92	Soybean	1998/99	Soybean
1985/86	Fallow	1992/93	Soybean and maize		

automatic titration/distillation unit. Total C analysis was performed using a total C and N analyser (LECO model CHN 600, Leco Corp. St Joseph, MI, USA) and the ^{13}C isotopic abundance was determined using a continuous-flow isotope-ratio mass spectrometer (Finnigan DeltaPlus mass spectrometer coupled to the output of a Carlo Erba EA 1108 total C and N analyser – Finnigan MAT, Bremen, Germany).

Results and Discussion

There were no significant differences in the concentrations of silt+clay between the different experimental plots or between depths (mean 51.4±0.9 %). However, the soil under the area of native vegetation was significantly higher in silt+clay ($P<0.05$ – mean 56.3± 1.7 %). To a depth of 40 cm the bulk density of the soil under the native Cerrado vegetation was significantly ($P<0.05$) lower than that under any of the experimental plots. However, below 40 cm there were no significant differences in this parameter between any of the tillage treatments or between these plots and the area under native vegetation. These results suggest that the bulk density of the soil under the experimental plots was originally very similar to the nearby area under native vegetation but the mechanical operations carried out over the 19 years of the experiment compacted the superficial layers of the soil. The total soil mass to 100 cm depth under the native vegetation amounted to 9610 Mg ha^{-1}, compared to a mean of 10825 Mg ha^{-1} for the experimental plots. The plots tilled with the mouldboard plough caused a greater soil compaction than the disc plough or zero tillage (11050, 10775 and 10651 Mg soil ha^{-1} to 100cm depth, respectively).

The C content of the soil under the native vegetation decreased from 39.7 g C kg $soil^{-1}$ in the 0-5 cm depth interval to 11.4 g kg^{-1} at 80-100 cm depth. Under the ZT treatments these values ranged from 24.9 % to 7.6 % lower for the 0-5 and 80-100 cm depth intervals, respectively. Under the ploughed treatments the C content of the soil was even lower, ranging from 40.3 to 12.4 % lower for the 0-5 and 80-100 cm depth intervals, respectively. The soil C stocks were corrected for an equal mass of soil (that in the native vegetation profile) as described by Neill et al. (1997) and these are displayed in Fig. 1. As was to be expected there was no significant difference in C stocks between the two treatments managed under ZT. The use of the disc plough once a year prior to planting also did not significantly reduce soil C stocks. However, mouldboard ploughing before planting, or tillage twice a year with either disc or mouldboard plough, significantly reduced soil C stocks.

The data suggested that all treatments (ZT or CT) significantly lowered C stocks in comparison to that under the nearby native vegetation, but there is some reason to doubt this conclusion. The silt+clay content of the soil under the NV was higher than under the tillage plots. Feller and Beare (1997) cite many authors to show that soil C content is linearly related to soil silt+clay content with high positive regression coefficients. As the soil C content under the tillage plots was higher all the way down the profile, even below 40 cm depth where it would not be expected that tillage would make any significant effect on SOM content, it seems reasonable to assume that originally the soil C content of the NV area was higher than that under the area used for the tillage study. If the C stock under the NV area is corrected for its higher % silt+clay (by assuming that this parameter is directly proportional to C content) then the original C stock of the area used for the tillage study (NV*) falls to 186 Mg C ha^{-1}, which suggests that the use of the soil in this region for cropping under ZT had no significant negative impact on soil carbon stocks.

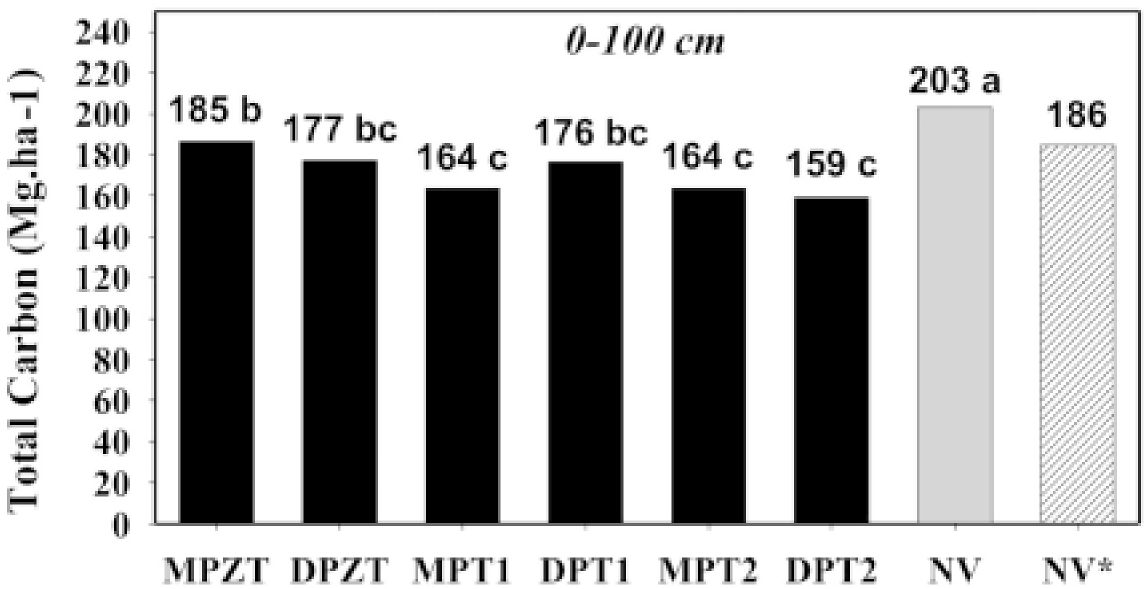

Fig. 1. Soil carbon stocks to 100 cm depth after 19 years of different tillage management compared to that of under a nearby area of native vegetation (NV). The total C stock for each treatment was corrected for an equal mass of soil in the profile. The treatments were as follows: MPZT and DPZT were managed under ZT after one initial tillage operation with a mouldboard plough or disc plough, respectively. The other 4 treatments were tilled with a mouldboard (MP) or disc plough (DP) either once just before planting (T1) or twice with a additional post-harvest operation to plough in crop residues (T2). NV* indicates C stock under the native vegetation corrected for the higher silt+clay in this soil (see text). The values above the bars are the total C stocks and where followed by the same letter are not significantly different at $P<0.05$ (Tukey test)

Data on soil N stocks and the effects of the different tillage techniques on the origin of the carbon in the profiles as deduced from the ^{13}C abundance data will be presented in the poster.

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