CHANGES IN SOIL PHYSICAL PROPERTIES AND SOIL ORGANIC CARBON FRACTIONS WITH CROPPING ON A RED BROWN EARTH SOIL

A.M. Whitbread, R.D.B. Lefroy, and **G.J. Blair**

Department of Agronomy and Soil Science, University of New England, Armidale, NSW 2351

Summary. Many agricultural practices have contributed to declining soil organic matter levels and deteriorating soil physical properties resulting in unsustainable food and fibre production systems. The chemical properties of a long term cultivated site were compared to those of an uncropped lightly grazed reference site on a red brown earth soil from Duri, NSW. Total carbon (CT) decreased from 3.74 % on the grazed site to 1.66 % on the cultivated site. Labile C (CL) was determined by oxidation with KMnO4 and changes in CT and CL used to calculate a Carbon Management Index (CMI). Cropping resulted in a CMI of 36.9. The 2000 to 4000 ?m aggregates from the cultivated site were found to be 5.4 % less stable to wetting than those from the reference site. Aggregates and particles <125 ?m increased by 8.3 % in the cultivated soil. The cultivated soil was therefore more prone to surface sealing and erosion processes. In the aggregates >250 ?m there was a greater decline in CL than CT as a result of cropping. This more labile carbon (CL) component appears to be related to higher aggregate stability on the grazed reference site.

INTRODUCTION

The organic matter content of soil is generally found to decrease rapidly following the clearing of native vegetation and the subsequent cultivation and cropping activities. Although total organic carbon of the soil declines due to cultivation, of particular concern is the decline in the more labile carbon fractions, which may be associated with soil nutrient dynamics (5) and have a role in the stabilisation of soil structure (1).

The rate of organic carbon decline varies with management practices, soil type and climatic conditions. Bowman *et al*. (3) investigated nutrient losses in soil cultivated for 0, 3, 20 and 60 years. Total C, N and P declined by 55-63% over 60 years, but more than half of this decline occurred in the first three years of cropping.

Numerous studies have linked organic carbon levels with aggregate stability, infiltration and soil strength, so a decrease in organic carbon is often associated with degrading soil physical conditions.

To develop more sustainable cropping systems, management systems which maintain and even improve soil organic matter levels need to be developed. A fenceline study was conducted to compare the structural characteristics of an uncropped soil to a soil with a long cropping history with conventional cultivation.

MATERIALS AND METHODS

Soil and site

The study was undertaken on a clayey Red Brown Earth at Duri on the north west slopes of NSW. A paired fenceline study was conducted to compare an uncropped lightly grazed site with an adjacent cultivated site on the same soil type and topographic position. The cropped site had been conventionally cultivated and sown to wheat and barley for approximately 60 years and was sparsely covered by lucerne at the time of the trial.

Wet Aggregate stability

Aggregate stability to wetting was measured using a wet sieving technique with five sieve sizes (125, 250, 500, 1000 and 2000 ?m). Three soil cores (72 mm internal diameter, 41 mm depth) were taken from the same positions on which the infiltration rate was measured with a disc permeameter. The samples were air dried and, in order that all soil samples had a similar energy input during crushing, soil was spread on a flat board with 4 mm ridges and rolled. The samples were then sieved to 4 mm and large particles of organic matter removed. Wet sieving was undertaken by placing a 30 g soil sample on top of the nest of five sieves, immersing the sieves in water and sieving for 10 minutes with a vertical motion of 18 mm amplitude at 30 movements per minute. The soil remaining on each sieve was then dried and weighed. This was a measure of the ability of aggregates to remain stable after wetting, i.e. water aggregate stability (WAS).

Nutrient and organic carbon levels

Total organic carbon and nitrogen were analysed on each of the sieved fractions by continuous flow catalytic combustion and mass spectrometry. The more labile soil organic carbon in the whole soil sample and each particle size fraction was measured by oxidation with 333 mM $KMnO_4$ (2).

Derivation of the Carbon Management Index

Since the continuity of C supply depends on both the total pool size and the lability (an estimate of turnover rate), both are taken into account in deriving a Carbon Management Index.

This can be achieved as follows:

a) Change in total C pool size

The loss of C from a soil with a large carbon pool is of less consequence than the loss of the same amount of C from a soil already depleted of C or which started with a smaller total C pool. Similarly, the more a soil has been depleted of carbon the more difficult it is to rehabilitate. To account for this a C Pool Index is calculated as follows:

C Pool Index (CPI) = <u>sample total C (mg/g)</u> = <u>CT sample</u>

reference total C (mg/g) CT reference

b) The loss of labile C is of greater consequence than the loss of non-labile C. To account for this a carbon Lability Index is calculated as follows:

Lability of C (L) = <u>C in fraction oxidized by KMnO</u>4 = <u>C</u>L

C remaining unoxidized by KMnO4 CNL

Lability Index (LI) = <u>Lability of C in sample soil</u>

Lability of C in reference soil

c) The Carbon Management Index (CMI) can then be calculated as follows:

Carbon Management Index (CMI) = C Pool Index x Lability Index = CPI x LI x 100

RESULTS AND DISCUSSION

Changes in soil physical properties

Wet sieving, using immersion wetting, revealed that cultivation resulted in a 5.4 % decline in water stable aggregates >2000 ?m. There was a corresponding 8.3 % increase in the <125 ?m fraction in the cultivated soil. These results demonstrate the structural degradation of soil aggregates due to destructive cropping practices. Tisdall and Oades (7) have found good structure for crop growth depends on the presence of water-stable aggregates of soil particles 1 - 10 mm in diameter. Surface sealing is associated with particles of about 100 µm in diameter, which can be estimated by the 125 ?m sieved fraction (4). The cultivated soil, which has a higher proportion of particles and aggregates in this size range compared to the grazed soil (26.6 % and 18.3 % respectively), is more likely to develop a soil crust, which can reduce infiltration of rainfall.

Changes in soil organic carbon

Total carbon decreased from 3.74 % in the reference soil to 1.60 % in the cultivated soil (Table 1). Labile C (CL) decreased from 9.66 mg/g in the reference soil to 3.70 mg/g with cultivation. This decline in both CT and CL resulted in a decline in LI, CPI and CMI (Table 1).

Table 1. Changes in total (CT), Labile (CL) and non-labile (CNL) Carbon and in the Carbon Management Index (CMI) due to cropping of a Red Brown Earth soil from Duri, NSW.

	CL	CNL	CT	L	LI	CPI	CMI
		mg/g					
Reference	9.66	27.64	37.38	0.349	-	-	-
Cropped	3.70	12.28	15.98	0.301	0.862	0.428	36.9

There was significantly more total carbon in each aggregate size fraction in the grazed than in the cropped soil and a significantly higher proportion of the carbon in the three fractions >500??m was oxidised by 333 mM KMnO4. This labile carbon component is responsible for much of the binding of particles into macroaggregates >250 ?m (e.g. polysaccharides, roots and fungal hyphae). Tisdall and Oades (7) have found that this size range of aggregates are bound by transient and temporary binding agents which are influenced largely by management. This is due to the extent which management controls root growth and the oxidation of organic carbon, eg. cultivation, rotations. Figure 1 illustrates the decline in CT and CL from the reference to the cultivated soil. Labile C (CL) declined more than CT in the fractions 250-2000 ?m. This decrease in CL correlates with lower wet aggregate stability (WAS) in the cultivated soil. The decline in WAS is associated with a decline in hydraulic conductivity (10 mm tension) from 210 mm/hr on the grazed site to 86 mm/hr on the cultivated site. The correlation between WAS and organic carbon in soil has been demonstrated in numerous studies (e.g. 6), with these correlations varying in goodness of fit. Most of the variation between studies results from the fact that only the more labile components of organic matter are responsible for water stable aggregation and this fraction is often more susceptible to management induced changes than total organic carbon. The KMnO4 oxidizable C appears to be a promising measure of this active component.

Aggregate Size Fraction (?m)

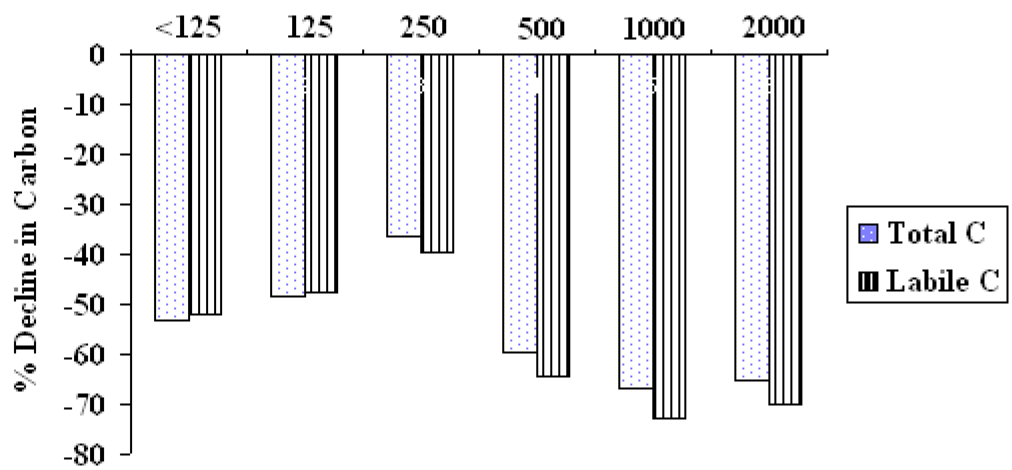

Figure 1. Decline in CT and CL in each aggregate fraction size due to cultivation of a Red Brown Earth from Duri NSW.

These results demonstrate the impact of continuous conventional cropping on organic carbon levels and soil structure. The widespread decline in crop yield and grain quality in many major grain producing regions can, most likely, be explained by declines in both chemical and physical fertility. The Carbon Management Index used here is a useful measure of such decline and should be evaluated more widely.

ACKNOWLEDGMENTS

The technical assistance of Leanne Lisle is gratefully acknowledged. The senior author was funded by a studentship from the Grains Research and Development Corporation. Other financial support was provided by the Australian Centre for International Agricultural Research.

REFERENCES

1. Allison, F.E. 1973. Developments in Soil Sci. 3., (Elsevier: Amsterdam). 637 pp.

2. Blair, G.J., Lefroy, R.D.B. and Lisle, L. 1995. Aust. J. Agric. Res. 46(7) (in press).

3. Bowman, R.A., Reeder, J.D. and Lober, R.W. 1990. Soil Sci. 150, 851-857.

4. Loch, R.J. 1994. Aust. J. Soil Res. 32, 687-700.

5. Parton, W.J., Schimel, D.S., Cole, C.V., and Ojima, D.S. 1987. Soil Sci. Soc. Amer. J. 51, 1173-1179.

6. Tisdall, J.M. and Oades, J.M. 1980. Aust. J. Soil Res. 18, 423-434.

7. Tisdall, J.M. and Oades, J.M. 1982. J. Soil Sci. 33, 141-163.