

SOIL CARBON FRACTIONS AS INDICATORS OF THE SUSTAINABILITY OF COTTON CROPPING SYSTEMS

Abdul Conteh, Graeme Blair, Rod Lefroy and Donald Macleod

CRC for Sustainable Cotton Production

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

INTRODUCTION

Cotton production in Australia is predominantly carried out on grey, red and brown cracking clays with self-mulching surfaces, and red-brown earths, which are hard alkaline duplex soils. A common management system for these soils for growing cotton in Australia has been outlined by Constable *et al.* (1992). This usually involves intensive cultivation which generally has involved some exploitation of accumulated soil organic matter (SOM) reserves. Under such intensive cropping systems, nutrient losses may be compensated for by fertiliser additions. The decline in SOM can lead to a deterioration in the physical condition of the soil. In addition, the economic and environmental impact of a heavily fertiliser-dependent cropping system may threaten long-term sustainability.

The development of sustainable cotton cropping systems requires the identification and monitoring of those soil variables that control system stability either by imparting resistance to change, or resilience after a change has occurred. The quality and quantity of SOM are such key variables that have significant impact on the sustainability of cropping systems. The assessment of the sustainability of cotton cropping systems therefore requires an understanding of the dynamics of SOM in soils under cotton production.

As a result of the complexity of organic matter in soils and its association with the mineral matrix, a wide range of approaches have been advocated for use in monitoring SOM dynamics resulting from a range of soil management practices. These approaches have been reviewed by Lefroy *et al.* (1994). Although valuable information regarding the range and functions of various organic matter components has been provided by these measurements, most of them are too expensive and sophisticated to be employed for monitoring

purposes. Total organic carbon (TOC) measurements by the method of Walkley and Black (1934) has been widely used. A drawback with the use of TOC measurements alone is that SOM changes are gradual, such that short-term changes in organic carbon may be difficult to detect against a high background level. Changes that can only be detected over several decades may not be useful in soil management decisions.

This work examines the potential value of a simple measurement of labile and nonlabile soil carbon fractions to provide widely applicable monitoring indicators to assess the sustainability of cotton cropping systems.

MATERIALS AND METHODS

The soil samples used for this study were collected from the 0 - 20 cm horizon from seven cotton growing regions of New South Wales and Queensland to give a total of 65 samples ranging widely in cropping histories and soil type. At each collection site, there was a reference soil (nearby uncropped) and a cropped soil. The cropping histories ranged from 1 year to 60 years with a wide variability in chemical properties. All samples were ground and sieved to less than 2 mm and a subsample ground and sieved to less than 0.5 mm for organic carbon fractionation. The procedure described by Blair *et al.* (1995) and Lefroy *et al.* (1993) was used to obtain the labile and nonlabile carbon fractions. Using the labile carbon (C_L) and nonlabile carbon (C_{NL}) contents obtained, the following indicators were developed:

i. Carbon Pool Index (CPI) : The loss of carbon from a soil with a large pool size is of less consequence than the loss of the same amount of C from a soil already depleted of carbon. Similarly it is more difficult to rehabilitate a soil depleted of carbon than one with a large pool. To account for this a carbon pool index is calculated taking into consideration the total carbon content (C_T) of a sample determined by catalytic combustion as compared to the carbon content of a nearby uncropped reference soil.

ii. Lability of soil carbon: The lability of soil carbon expresses the amount of labile carbon present in a given soil relative to the amount of nonlabile carbon in the same soil.

iii. **Lability Index (LI):** Losses occurring in labile organic carbon of a soil and its impact on the sustainability can be estimated from the lability index (Blair *et al.*, 1995).

iv. **Carbon Management Index (CMI)** = $CPI \times LI \times 100 (\%)$

RESULTS AND DISCUSSION

In nearly all of the soils examined, cultivation has resulted in a reduction in total carbon (C_T), labile carbon (C_L), nonlabile carbon (C_{NL}), and thus a reduction in the carbon pool index (CPI) and carbon management index (CMI). The decline in C_L was mostly larger than the decline in C_{NL} and C_T . The practical implication of these changes to the cotton farmer is the need to develop soil management strategies that will increase or maintain soil organic matter levels in cotton cropping systems.

The relative changes in the proportion of C_L to C_{NL} of the cropped soils relative to the reference soils are reflected in the lability index (LI). Results from the soils examined show a wide variation in the changes occurring in the lability index of the soil carbon during cropping. Unlike the general decrease observed in the carbon pool index as the soils were being cropped, some increases in the lability index were observed in a significant number of soils. The increases observed in the lability index could have resulted from increases in the relatively decomposable carbon relative to the recalcitrant carbon. This normally occurs in situations where organic matter with low C/N ratio or high plant residue quality index (Tian *et al.*, 1995) has been incorporated into the soil.

In situations where the lability index declines with cropping, the implications are that the ratio of labile to nonlabile carbon has decreased during cultivation of the soil. This could have resulted from soil management systems which lead to either a rapid decomposition of readily available carbon while maintaining the resistant carbon, or rapid transformation of available carbon to a resistant form, or, though increasing both the labile and nonlabile carbon, the conversion from labile to nonlabile carbon occurs at a greater rate than the rate of increase in the labile carbon.

To incorporate these indicators in a sustainability perspective, the CPI and the CMI were examined. For a system to be sustainable with respect to organic matter management, the CMI must be stabilized or increased.

The general changes occurring in the CPI of the soils in relation to the length of cropping are represented in a polynomial relationship as shown in Figure 1.

The relationship shows a rapid decline in the CPI of all soils cropped in the first 30 years. As the cropping period extends beyond 30 years, the carbon pool index gradually improves. Since the CPI expresses the total carbon of a cultivated soil as a ratio of the total carbon in a reference soil, the initial rapid decline in the CPI is a direct result of the reductions in the total soil carbon during initial cultivation. The gradual increase observed in those soils which have been cropped for more than 30 years demonstrate the potential for the development of cotton cropping systems that will improve the carbon status of soils.

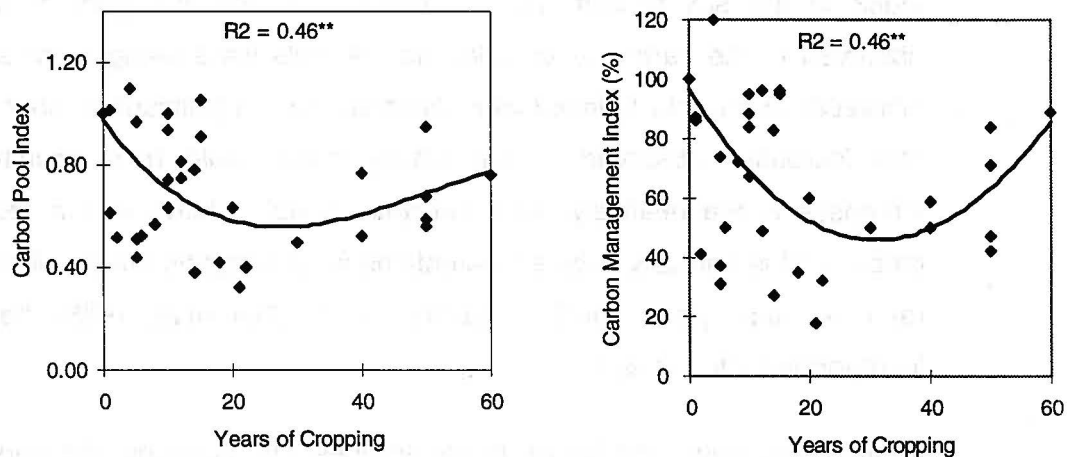


Figure 1. Changes in CPI and CMI with length of cropping

An examination of the cropping histories of all sites showed that out of the 65 sites sampled, only seven of these sites have been cropped for more than 30 years, five of which are from the Darling Downs. Background information on these sites show that the dominant cropping systems carried out in these sites are traditional mixed cropping in which legumes, sorghum and cereals have

been rotated with cotton. The incorporation of residues from these rotation crops could have resulted in the increases in the CPI. Although similar trends were observed in the Carbon Management Index (CMI) as in the Carbon Pool Index (CPI), the CMI show higher rates of change with length of cropping than the CPI (Figure 1). This is an indication of the complex dynamics occurring in the easily decomposable and resistant components of soil carbon.

These indicators will be further examined in the light of results obtained from long-term rotation experiments currently being carried out under both irrigated and dryland conditions by the Cooperative Research Centre for Sustainable Cotton Production. Efforts are also presently underway to acquire some understanding of the carbon components found in the labile and nonlabile fractions by means of Nuclear Magnetic Resonance (NMR) and Near Infrared Reflectance (NIR) Spectroscopic techniques. Data for the relationship between the various carbon indices and other soil chemical properties and cotton seedling growth are presently being processed and will be reported in a later presentation.

ACKNOWLEDGEMENTS

This study was funded by the Cotton Research and Development Corporation. Technical assistance from Michael Crestani, Judy Kenny and Leanne Lisle is gratefully acknowledged.

REFERENCES

- Blair, G.J., Lefroy, R.D.B. and Lisle, L. 1995. *Aust. J. Agric. Res.* **46**: 1459-466.
- Constable, G.A., Rochester, I.J. and Daniels, I.G. 1992. *Soil and Tillage Res.* **23**: 41 - 59.
- Lefroy, R.D.B., Blair, G.J. and Strong, W.M. 1993. *Pl. Soil* **155/156**: 399-402.
- Lefroy, R.D.B., Blair, G.J. and Conteh, A. 1994. *ACIAR Proceedings* **56**: 149-156.
- Tian, G., Brussard, L. and Kang, B.T. 1995. *Appl. Soil Ecol.* **2**: 25 - 32.
- Walkley, A. and Black, I.A. 1934. *Soil Sci.* **37**: 29 - 38.

