Effects of pasture leys, tillage system and crop frequency on C dynamics, soil physical and biological properties

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Abstract

Maintenance of soil organic carbon (C) is an essential component of sustainable cropping systems, especially on easily degradable soils like the Red Ferrosols of north and southeast Qld. Soil C stores have declined by up to 100 t C/ha due to past management practices, but a combination of increased residue input and reduced tillage can allow to increase or at least maintain soil organic C stores. Periodic pasture leys between cropping phases are the most effective means of improving soil C and associated soil physical and biological fertility.

Key Words

Red Ferrosols, organic carbon, tillage, leys, microbial biomass

Introduction

Declining soil organic C status is a key issue affecting the long term sustainability of cropping on the Red Ferrosol soils of the inland Burnett and Atherton Tableland. Paired site studies in each region (Bridge and Bell, 1994; Bell *et al*., 1998) showed significantly lower soil organic C concentrations in cropped soils, and these lower C concentrations were associated with poorer soil physical and chemical attributes. Ley pastures were shown to be effective in raising soil organic C status (Bell *et al.*, 1997), but the fate of that improved soil C store upon a return to cropping has not yet been described.

Cropping systems in the Red Ferrosol areas are complex, with a diverse range of crop species suited to an opportunity cropping system that can capitalise on summer or winter rainfall. There has traditionally been a high frequency of legumes in the rotation (peanuts [*Arachis hypogaea*] or soybeans [*Glycine max*] were the most prominent), although this has changed as opportunity cropping has become more widespread. The impact of changes in cropping frequency and the mix of grass and legume species on soil C stores has not been determined. This paper quantifies the loss of soil C stores on these soils in north and southeast Qld, and assesses the impact of crop rotation and tillage system on C dynamics and soil microbial activity.

Methods

The decline in soil C due to conventional cropping was determined by comparing C stocks in 90cm soil profiles from paired sites under virgin rainforest, scrub or pasture and continuously cropped soils. Similar approaches were used in two long term studies at Kingaroy, in the inland Burnett of southeast Qld, to compare the effect of crop frequency and rotation (Redvale site, described in Bell *et al*., 2003) and tillage system with or without a preceding ley pasture (Goodger site, described in Bell *et al*. 1997). Soil C stocks were assessed by soil coring and measurement of bulk density, with C analysed by a Leco C analyser (total soil C) or by measuring the amount of C oxidised by 33mM $KMnO_4$ (labile C). Microbial biomass C and N were determined to depths of 30cm at the Goodger site using the chloroform fumigation method.

Results and Discussion

The loss of soil C under cropping was primarily a function of the climate and original vegetation, with profile totals in cropped soils in most districts reaching similar low levels. Total carbon loss ranged from *ca.* 100 t C/ha in the areas originally under rainforest on the Atherton Tableland and under softwood scrub in the inland Burnett, to less than 20 t C/ha in the open Eucalypt woodlands and dry forests in both regions (Fig. 1).

Long term experiments that examined the impact of maize cropping and grass pasture leys of varying duration, compared to monoculture peanuts (organic $C_{0\text{-}10cm}$ = 1.72%), showed that while rotations of the same duration produced similar impacts on soil organic C, the impact of species (grass pasture compared to maize cropping) on the amount of labile C was quite different (Fig. 2). Grass leys produced much larger relative changes in labile C than total C, and this suggested that while the higher labile C after a ley may produce greater beneficial effects on key soil properties like aggregate stability (Bell *et al.*, 1998), the effects may be more rapidly lost as the labile C was mineralised upon a return to conventional cropping. Rates of C loss calculated from this study supported that hypothesis, with soil C declining 30% faster after a 2 year grass ley than a 2 year maize rotation when returned to a conventionally tilled peanut monoculture (ie. 0.92 t C/ha/year compared to 0.71 t C/ha/year).

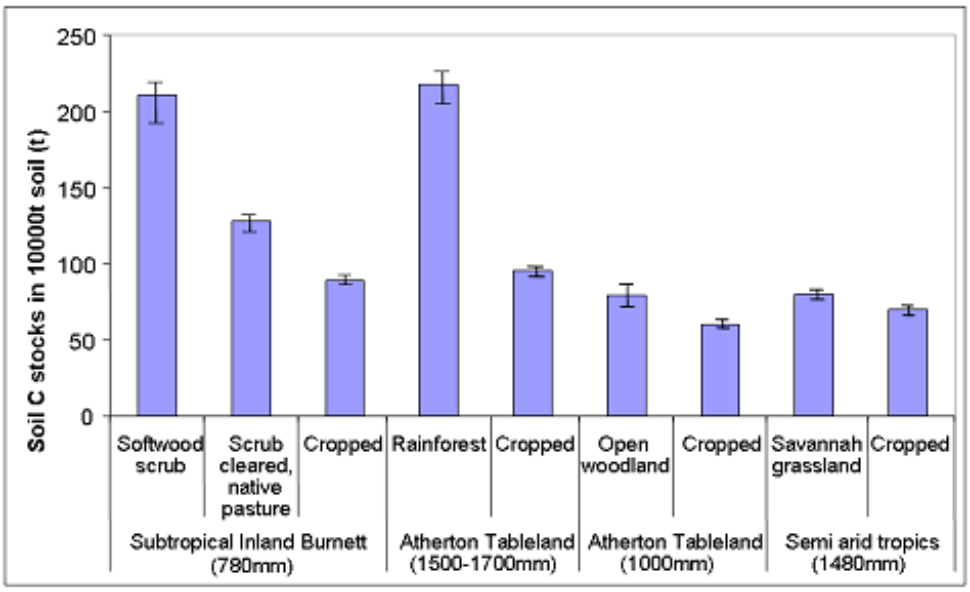

Fig. 1. Effect of cropping on soil C storage in Red Ferrosols in north and southeast Qld.

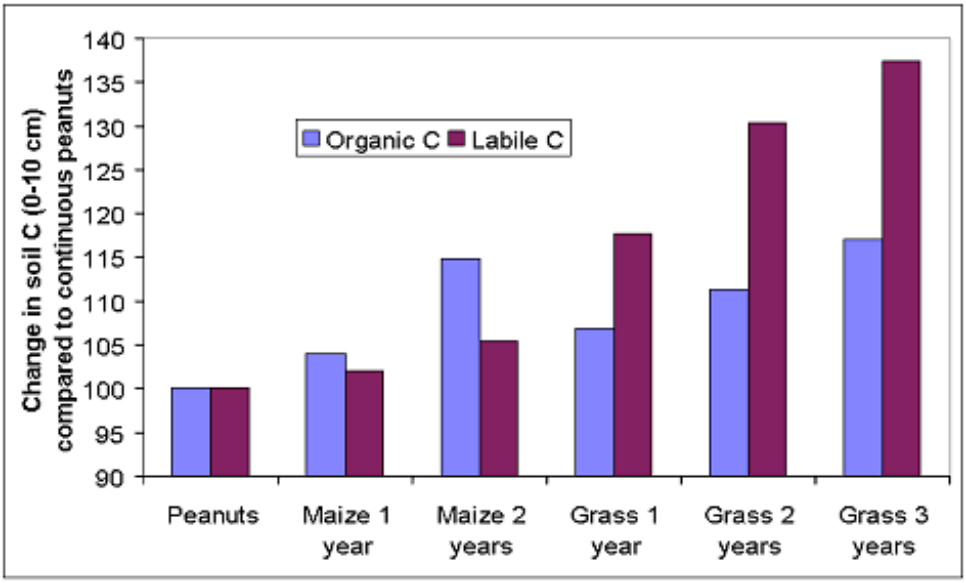

Fig. 2. Relative impact of maize and grass leys on soil C in the top 10cm of cultivated Ferrosols.

Reducing tillage during a cropping phase seems the most likely way to retain soil C accumulated during grass leys. The Goodger tillage study compared a 4 year grass pasture ley to continuous cropping, with both systems cropped using direct drill or full tillage over the next 4 years. The 4 year ley produced no increase in soil C, but soil also contained *ca*. 10 t C/ha of undecomposed roots and rhizomes in the top 20cm. At the end of the crop period the direct drill ley plots contained 17% more soil C in the top 20cm of the profile (equivalent to *ca*. 4.5 t C/ha – Fig. 3). However, ley plots that had been conventionally tilled returned identical soil C stocks as soil that had been continuously cropped over the whole period. Interestingly, changing tillage system in continuously cropped soil had little impact on soil C stocks, although both total and labile C were more concentrated in the top 5-10cm in direct drill. Microbial biomass C and N followed similar trends as soil C, but the response to a ley followed by direct drill (35-37% increase in both microbial C and N) was larger than the proportional increase in soil organic C and there was still a slight residual effect of the ley in conventionally tilled plots (13% more microbial biomass).

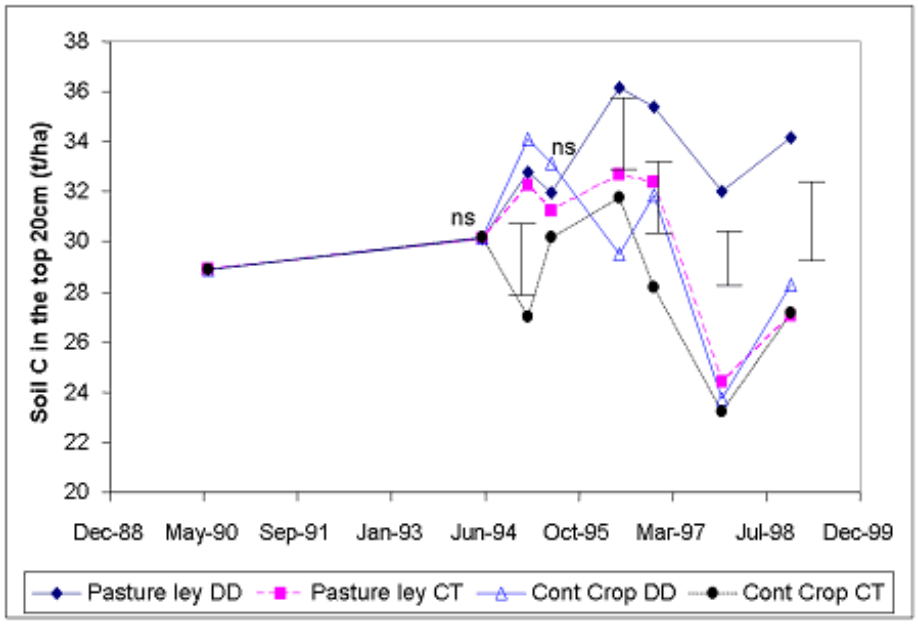

Fig. 3. Effects of a ley phase and subsequent tillage on soil C storage in a Ferrsol near Kingaroy.

Conclusion

Maintenance of soil C is a key issue for the long term sustainability of cropping systems on the Red Ferrosol soils of Qld, with large losses recorded in some soils due to inappropriate management practices. Ley pastures are the most effective way of improving soil organic C status in degraded soils, with relatively greater impacts on labile C components than on total organic C. However, this increased soil C lability after a ley will result in increased rates of C mineralisation upon resumption of cropping, unless the frequency and severity of tillage can be greatly reduced.

References

Bell, MJ, Bridge, BJ, Harch, GR, and Orange, DN (1997). Physical rehabilitation of degraded Krasnozems using ley pastures. Australian Journal of Soil Research 35, 1093-113.

Bell MJ, Harch GR, Tatnell J and the late KJ Middleton (2003). The impact of crop rotation on peanut productivity in rainfed cropping systems. In: "Solutions for a better environment".Proceedings of the 11th Australian Agronomy Conference, 2-6 Feb. 2003, Geelong, Victoria. Australian Society of Agronomy.

Bell, MJ, Moody, PW, Connolly, RD, Harch, GR, Want, PS and Yo, SA (1998). Development of a carbon-based sustainability index for Ferrosols in rainfed cropping systems. Proceedings 9th Australian Agronomy Conference, Charles Sturt University, Wagga Wagga, NSW.

Bridge, BJ and Bell, MJ (1994). Effect of cropping on the physical fertility of krasnozems. Australian. Journal of Soil Research 32, 1253-1273.