Soil carbon pools and building blocks: explaining the effects of tillage & stubble management

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Key messages

- Stable soil organic matter contains carbon, nitrogen, phosphorus and sulphur (CNPS) in predictable and constant proportions.
- The supply of N, P or S (and not just C input) can limit the formation of stable soil organic matter.
- Carbon sequestration and greenhouse gas emission from soil can be affected by limited nutrients.

Background

Soil C in the topsoil (0-15cm) layer has been monitored every 5 years during the Harden long-term experiment. Averaged over treatments, soil C decreased by one third over twenty years and even decreased where all of the stubble was incorporated each year. One hypothesis is that a lack of stabilising nutrients (N, P and S) and not a lack of C may limit the formation of stable soil organic matter, commonly referred to as humus. These stabilising nutrients act like the mortar in a brick wall to stabilise humus, and like the components of mortar must be present in the right proportions. Adding large amounts of crop residue which is normally rich in C but lacking in these nutrients may be limiting soil C build-up.

Recent studies

Soil from the Harden long-term site, and other sites in Australia have been used to investigate the effect of N, P and S availability on the formation of the stable portion of humus. The aim is to evaluate a range of soils to test the hypothesis that humus has constant proportions C:N:P:S.

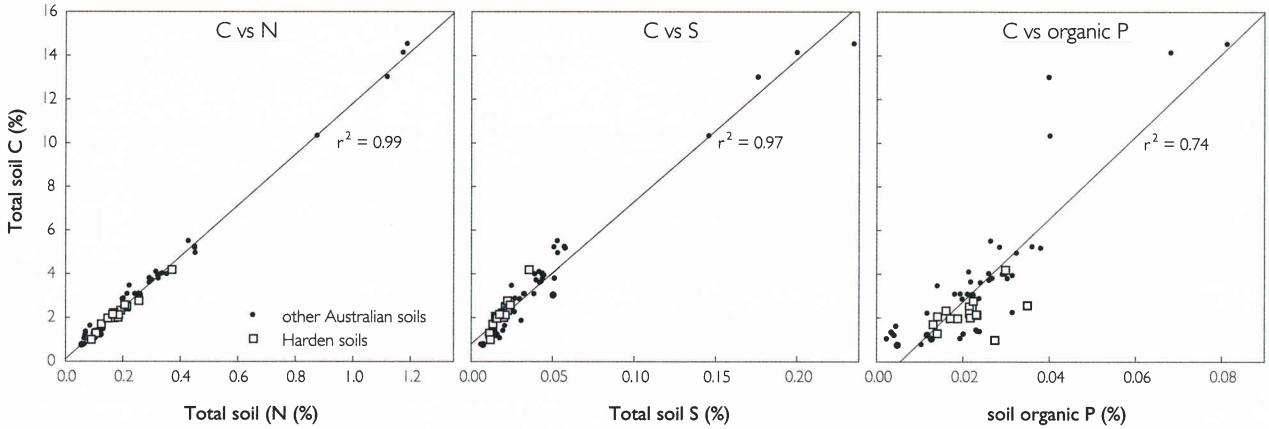
Farmers throughout southern Australia sent 59 soil samples for analysis. The samples included a wide range or crop and pasture soils and several that had never been farmed. The cropped soils had been regularly fertilised while the pastures soils had been irregularly or rarely fertilised. A second part of the study is incorporating fresh stubble with and without extra nutrients to evaluate the amount of humus formed.

The Pools

The plant residue or "light fraction" in soil (named because they float in water) should be separated from the mineral or "heavy" fraction before analysis. Humus is usually associated with the heavy mineral fraction and it is the humus that we hypothesise has a constant ratio of C:N:P:S. Three soils with different management histories from the Harden area (M Hufton) showed up to 100t/ha of "light fraction" in top 10cm of virgin or pasture soils compared with 10 t/ha in cropped soils. If left in the soil during analysis the ratios of nutrients vary widely between soils, while removing them leads to similar soil C values (Table 1).

> Table 1. Analysis of three Harden soils with light fraction included or light fraction removed.

	C	N	P	S		C:N	C:P	C:S
Soils with light fraction included	(%)					(ratio)		
Virgin soil, never farmed, never fertilised (> 100t light fraction ha-1)	3.503	0.232	0.024	0.022		15.1	148	160
Long term pasture (> 100t light fraction ha-1)	3.959	0.351	0.037	0.031		11.3	106	128
Long term cropping (< 10t light fraction ha-1)	2.123	0.18	0.034	0.017		11.8	62	121
Soils with light fraction removed								
Virgin soil, never farmed, never fertilised (> 100t light fraction ha-1)	2.061	0.165	0.021	0.015		12.5	99	139
Long term pasture (> 100t light fraction ha-1)	2.765	0.256	0.035	0.022		10.8	80	123
Long term cropping (< 10t light fraction ha-1)	1.978	0.169	0.033	0.015		11.7	61	130



> Figure 1. C:N, C:S and C:organic P for 59 Australian soils.

Some researchers believe it is the loss of this light fraction material that is largely responsible for the reduction in soil C levels after virgin soils are cropped. This challenges the view that cropping always leads to a loss of "true" or "stable" soil C.

The Building Blocks

The constant proportion of C:N:P:S suggested by the literature for humus is 10,000:833:200:143 (Himes 1998). The 59 Australian soils were cleaned (the light fraction removed) and analysed for total C, N, S and organic P. There was a strong relationship between C, N, S and organic P in the soils (Fig. 1). The data suggests that 10,000 units of humus C requires 844 units N and 141 units S, similar to ratios reported in the literature. However the Australian data suggests that 10,000 units of humus C requires only 53 units P, compared to 200 units P suggested by literature. Further research is needed to resolve the difference.

Practical Implications

Differences in soil C between tillage and stubble management systems are mostly due to differences in the amount of the light fraction of organic matter and not to humus. Soils should be fractionated into light and heavy fractions before analysis to determine the C in each pool and to determine if management practices affect both pools equally. If carbon trading becomes a reality then knowing which pool one's soil carbon is in and how it might react to different soil management may be an issue of prime importance.

Humus, generally considered to be a very stable form of soil C, always contains C, N, P and S and in precise proportions. The supply of N, P or S (and not just C inputs) could limit the formation of humus, reduce the decomposition of plant residues, leading to a build-up of light fraction material, and increase the proportion greenhouse gases emitted when residues eventually decompose.

Further reading

Kirkby, C.A., Kirkegaard, J.A., Richardson, A.E., Wade, L.J., Blanchard, C. and Batten, G. (2009) Stable soil organic matter: a comparison of CNPS ratios in Australian and International soils (submitted)