# Can soil organic carbon be increased in a continuous cropping system in the low to medium rainfall zone?

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**Key Findings**

- Eight trial sites were established across South Eastern Australia to investigate whether soil organic carbon levels can be increased in no-till farming systems, inclusive of adding nutrients to aid the biological breakdown of stubble into soil organic matter.
- After three or five years of treatment, no increase in soil organic carbon could be confirmed across four trial sites. However, it is well known that no-till and stubble retention protects the soil from wind and water erosion and over a longer time-frame soil organic carbon levels may increase. But, based on these results it is likely that any potential increase in soil organic carbon will be small.

**Why do the trial?**

Soil organic matter has physical, chemical and biological functions in soil. Increasing soil organic matter levels may improve the capacity of these functions in the soil, thereby improving the soil's resilience to degradation and possibly improving the soils productivity. Increasing soil organic matter also sequesters atmospheric $CO_2$ which acts as a sink for greenhouse gas emissions.

Increasing soil organic matter on broad-acre farms in the Australian wheat-sheep zone has been very difficult to achieve with long term trials showing little or no increase in soil organic carbon regardless of management practices imposed. Recent research undertaken by CSIRO at a medium to high rainfall site in NSW, showed that increasing soil organic carbon was possible if residues are pulverised and incorporated with a rotary cultivator together with an application of sufficient fertiliser nutrients (N, P and S) to enhance soil biological activity to break down the crop residues into soil organic matter (Kirkby et al. 2016). This innovation was adapted to broadacre cropping methods in the current study and tested over a three and five-year cropping rotation at eight sites across the southern grain belt. The sites were located at Minnipa, Hart, Birchip and Temora for five years, and Winchelsea, Cressy Tasmania, Condobolin and Ouyen.

Soil organic matter consists of three fractions – Particulate (POC), Humus (HOC) and Resistant Organic Carbon (ROC). The three fractions have different physical, chemical and biological functions in soils. The proportions of the three fractions as components of the soil organic matter were measured and are reported in these results.

| Particulate organic carbon (POC) | Humus organic carbon (HOC) |
|---|---|
| Reducing soil crusting and improving infiltration,<br>Improving soil friability,<br>Lowering soil bulk density,<br>Increasing plant available water (note – POC has a small effect on the drained upper limit of the soil because clay-loam soils in relatively dry environments are rarely at drained upper limit),<br>Storage and cycling of nutrients,<br>Food source for soil micro-organisms | Improving soil friability<br>Storage and cycling of nutrients<br>Soil pH buffer (reducing acidification)<br>Improving the Cation Exchange Capacity (CEC)<br>Food source for soil micro-organisms<br>Mineralisation of ammonium and nitrate (plant available N)<br>**Resistant organic carbon (ROC)**<br>Binding detrimental ions (such as aluminium),<br>Some effect on the cation exchange capacity |

It is clear that if soil organic carbon levels can be increased, the benefits for improving the soil physical, chemical and biological condition would be significant.

**How was it done?**

Eight sites were established in South Eastern Australia to test whether soil organic carbon levels can be increased by retaining stubble and applying additional nutrients (N, P and S) to enhance soil biological activity to breakdown the stubble into soil organic matter. Four of these sites were maintained for three years, the other four sites for five years (including the Hart site).

The trial compared stubble retention versus stubble removal, with the application of additional fertiliser nutrients to aid the breakdown of stubbles into soil organic matter over a cropping rotation. Each season the stubble load of the previous crop was determined, and additional nutrients were applied to match the given stubble load as a treatment to enhance the breakdown of stubble into soil organic matter.

Soil microbes use stubble as a food source and convert stubble into humus. Stubble is carbon rich relative to the other essential nutrients required by microbes and additional nutrients are required by the soil microbes to convert stubble into humus. The amount of NPS required by the microbial population to break down stubble into humus is worked out from:

- 1 tonne of carbon as humus contains 80 kg N, 20 kg P and 14 kg S
- 1 tonne of wheat stubble contains 450 kg carbon, of which 70% is lost to the atmosphere (hence 135 kg carbon is retained for every tonne of stubble)
- For the soil microbes to convert this amount of stubble carbon into humus requires 10.8 kg N, 2.7 kg P and 1.9 kg S
- 1 tonne of wheat stubble already contains 5 kg N, 0.5 kg P and 1 kg S
- Hence for every tonne of wheat stubble an additional 5.8 kg N, 2.2 kg P and 0.9 kg S is required to enable the soil microbes to break down stubble into humus.

The trial was established at Hart in 2012. Treatments were replicated 4 times and consisted of:

- Stubble: (i) retained and left standing;
  (ii) cultivated and incorporated prior to sowing;
  (iii) removed prior to sowing.
- Nutrients: (i) normal application of NPS to optimise production;
  (ii) additional nutrients applied at sowing to enhance microbial activity to breakdown stubble into soil organic matter. (Note – the Yield Prophet model was used to optimise N requirements in-crop)

*Note: at Hart an additional treatment was included – double the stubble load plus additional nutrients.*

The trial ran for five cropping seasons (2012 to 2016). At the end of the trial, in March 2017, all treatment plots were soil sampled to 30 cm depth with three replicate cores taken in each plot. Each core was divided into 0-10 and 10-30 cm sections. Each sample was air dried and analysed for bulk density, total soil organic carbon (Leco) and the fractions of soil organic matter – Particulate (POC), Humus (HOC) and Resistant (ROC) using MIR.

*Note: soil organic carbon values measured with the Leco technique are generally 20% higher than the more traditionally used analysis for soil organic carbon with the Walkley Black technique.*

Treatment crop yields were recorded.

**What happened?**

*Trial rotation and crop yield*

Over the five-year trial there were no differences in yield between treatments (Table 1). This result implies that the additional nutrients applied as a treatment were not used by the crop for yield but were available to the soil microbes for potential stubble breakdown into humus.

*Table 1. Crop rotation and yield over five years of treatments (2012 to 2016) at Hart.*

| **Stubble treatment** | **Nutrition treatment** | **Grain yield (t/ha)** | | | | |
|---|---|---|---|---|---|---|
| | | **2012** | **2013** | **2014** | **2015** | **2016** |
| GSR (April to October rainfall mm) | | 168 | 303 | 280 | 228 | 356 |
| Crop type / variety | | Wheat Gladius | Barley Fathom | Wheat Wallup | Canola 44Y89 | Wheat EmuRock |
| Stubble removed | Normal practice | 1.8 | 6.0 | 4.0 | 0.7 | 4.2 |
| Stubble removed | " plus NPS | 2.1 | 5.9 | 4.0 | 0.7 | 4.2 |
| Stubble standing | Normal practice | 1.7 | 5.8 | 3.9 | 0.7 | 4.0 |
| Stubble standing | " plus NPS | 1.8 | 6.0 | 4.3 | 0.7 | 4.9 |
| Stubble incorporated | Normal practice | 1.9 | 5.9 | 4.0 | 0.7 | 4.0 |
| Stubble incorporated | " plus NPS | 1.8 | 5.9 | 4.1 | 0.7 | 4.6 |
| | ***LSD (0.05)*** | ***ns*** | ***ns*** | ***ns*** | ***ns*** | ***ns*** |

At the other three sites with a five year rotation (Minnipa, Birchip and Temora) there were no differences in crop yield between treatments in any season.

*Change in soil organic carbon after five years of treatments*

The average soil organic carbon content of the topsoil (0-10 cm) at Hart was 1.7% and 1.0% in the subsoil (10-30 cm). After five years of trial work there was no difference in total soil organic carbon (t/ha, 0-30 cm) at Hart (Table 2) nor at the other three trial sites. On average the Hart site contained 51.3 t soil C/ ha in the top 30 cm. This value is at the higher end of previous soil organic carbon stocks reported for the Mid-North 20.3 – 63. 2 t/ha across a range of sites (MacDonald et al. 2012).

*Table 2. Soil organic carbon stock (t/ha, 0-30cm) after five years of treatments (2012 to 2016) at four trial sites.*

| Stubble treatment | Nutrition treatment | Soil C (Leco) 0-30cm (t/ha) | | | |
|---|---|---|---|---|---|
| | | EPARF | Hart | BCG | FarmLink |
| Stubble removed | Normal practice | 38.1 | 50.5 | 31.8 | 42.9 |
| Stubble removed | " plus NPS | 38.3 | 53.0 | 29.8 | 44.0 |
| Stubble standing | Normal practice | 37.0 | 49.7 | 32.0 | 42.5 |
| Stubble standing | " plus NPS | 35.7 | 49.7 | 31.9 | 44.5 |
| Stubble incorporated | Normal practice | 37.9 | 51.9 | 30.9 | 39.8 |
| Stubble incorporated | " plus NPS | 39.0 | 53.0 | 31.4 | 41.5 |
| Double stubble | Plus NPS | | 52.6* | | |
| | ***LSD (P=0.05)*** | ***ns*** | ***ns*** | ***ns*** | ***ns*** |

* Annual application of double the stubble load plus additional NPS at Hart only.

At the Hart site an extra treatment was included – each year the stubble load was doubled and the required additional nutrients were applied. This treatment did not result in higher soil organic carbon levels (Table 2) after five years of experimentation.

*Soil organic carbon fractions*

At Hart and the other three trial sites the treatments did not result in changes in the soil organic matter fractions. After five years of treatment applications the soil organic carbon fraction proportions were: 13.6% POC, 56.8% HOC and 29.6% ROC of total soil organic carbon content.

**What does this mean?**

In the South Eastern Australian low to medium rainfall zone it is difficult to increase soil organic carbon levels using current cropping techniques, even if additional nutrients are applied to enhance soil microbial activity for the breakdown of stubble into soil organic matter. Previous research undertaken in southern NSW where significant increases in soil organic carbon were measured (Kirkby et al. 2016), included pulverising the residues with a flail mulcher followed by incorporation with a rotary cultivator. This treatment was not applied in our trials because we regarded it unlikely that farmers could be persuaded to pulverise stubbles and cultivate the soil, increasing the risk of soil erosion in low to medium rainfall environments, to see a potential increase in soil organic carbon.

At all eight sites (either managed for three of five years) the result was the same – an increase in soil organic carbon could not be demonstrated with the treatments outlined in this paper.

The take home message in relation to soil organic carbon is that it is unlikely to increase with current cropping practices. But it is well known that no-till and stubble retention protects the soil from wind and water erosion and over a longer time-frame soil organic carbon levels may increase. However, based on these results it is likely that any potential increases in soil organic carbon will be small.

**References**

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