RiverinePlains

Stubble management guidelines for the Riverine Plains

NUMBER
04

Stubble and soil carbon

Key points

Stubble is mainly comprised of carbon, with smaller amounts of other nutrients such as nitrogen, phosphorus and sulphur.

Soil carbon is the main component of soil organic matter.

Conversion of carbon in stubble to soil carbon by microbes requires water and nutrients.

Climate, soil moisture and soil type affect the rate of stubble breakdown and the build-up of soil organic matter.

There were no differences in soil carbon across burnt, standing, mulched or disced stubble treatments during a three-year trial conducted in the Riverine Plains region, even when post-harvest applications of fertiliser were made to support microbial activity.

Greenhouse gas emissions may be increased by the application of nutrients to feed microbes.

Soil carbon builds slowly in cropping systems and can be difficult to measure.

Retained stubble systems are commonly regarded as beneficial for the accumulation of organic matter and soil carbon in soils, however increasing the amount of total soil carbon in cropping systems is notoriously difficult to achieve.

Stubbles are generally rich in carbon but low in other nutrients, with each tonne of wheat cereal typically containing around 450kg of carbon and much lower proportions of other nutrients (Table 1).

With cereal stubbles loads in the Riverine Plains region typically ranging from 6–9t/ha it follows that our local soils should be high in soil carbon given the large amounts of carbon-rich crop material produced each year. However, even when growers apply full stubble retention to no-till stubble retained (NTSR) systems, soil carbon may not measurably increase. This seems contrary to common sense which suggests that retained stubble will increase the soil carbon content.

The difference between soil organic matter and soil carbon

Soil organic matter (SOM):

Soil organic matter consists of organic material derived from living organisms, including plants, animals and micro-organisms. SOM makes up 2–10% of the total soil mass and is approximately 58% carbon with hydrogen, oxygen, nitrogen, phosphorus, sulphur, potassium, calcium and magnesium also present in smaller amounts. Soil organic matter plays an important role in the physical, chemical and biological function of soils

Soil organic matter improves aeration and the physical structure of the soil. It increases plant available water (PAW), lowers bulk density and protects soil from wind or water erosion. It also contributes to the cation exchange capacity (CEC) of the soil, binding to nutrients such as ammonium, calcium, magnesium and potassium and buffering against acidification and maintaining availability of phosphorus (P). Soil organic matter also provides energy for microorganisms to convert unavailable forms of soil nitrogen into plant available forms (nitrate and ammonium), through the process of mineralisation.

Soil organic carbon is a component of soil organic matter

The carbon found in soil organic matter is referred to as soil organic carbon. Soil organic carbon can be decomposed by microbes and is distinct from other chemical forms of carbon in soil, such as carbonates, which cannot be decomposed by microbes. Carbonates are also measured in a total soil carbon test but are omitted from a soil *organic carbon* test.

1 TONNE of wheat stubble contains around 450kg carbon KG

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TABLE 1 Relative proportions of N, P & S per 1000kg C found in humus and in wheat stubble

	Carbon present (kg)	Nitrogen present (kg N/1000kg C)	Phosphorus present (kg P/1000kg C)	Sulphur present (kg S/1000kg C)
Soil organic matter	1000	80	20	14
Wheat stubble	1000	11	1.1	2.2

Source: Soil Organic Matters Fact Sheet 2 (GRDC)

Soil organic carbon consists of a range of compounds which can be split into several fractions and each fraction has a different function, with the type that supports nutrient cycling different to the pool that supports carbon sequestration.

In Australia, the Australian Soil Carbon in Agriculture Research Program defines the fractions of soil carbon as:

Particulate organic carbon (POC) — organic carbon >52µm* in size, comprised of partially decomposed plant and animal material. Particulate organic carbon usually represents 10–60% of total SOM.

Humus organic carbon (HOC) — organic carbon <52µm in size. It consists of fine decomposed material present as organic molecules attached to clay particles. Binding with clays protects HOC from microbial breakdown and makes it more stable. The long residence time and stability in soil is why HOC is the form of carbon measured to determine sequestration. Humus organic carbon makes up 20–80% of SOM.

Recalcitrant organic carbon (ROC) — this pool is made up of charcoal and other forms of relatively inert carbon. Recalcitrant organic carbon represents 10–60% of SOM. Recalcitrant organic carbon is largely unavailable to micro-organisms, so can take hundreds of years to decompose. Highly weathered soils and soils with a history of burning have a high proportion of ROC.

**1 micrometre (µm) = 0.001mm*

It is time consuming and expensive to measure the different carbon pools in a soil sample. As such, the measurement of carbon fractions is not part of routine soil testing and is generally only carried out in research programs. This makes it difficult to identify which types of carbon dominate any given soil.

Soils with a history of perennial pastures, either continuous or as part of a long-term rotation, are more likely to have a higher organic matter content (and therefore soil carbon content) than similar soils under continuous annual cropping. In addition, as soils in the higher-rainfall areas tend to produce more plant biomass (shoot and root matter), they often have higher organic matter contents than soils in the medium and low-rainfall zones if plant residues have been retained.

Farming systems that maximise the number of days per year when plants are growing will have a greater potential for soil organic matter and soil carbon build up.

How does soil carbon form in cropping systems?

Soil organic matter, including the soil carbon fraction, is made up of the remains of bacteria and other microorganisms that consume and break down crop and pasture residues

While soil microbes use carbon for energy, they also need water and other nutrients, such as phosphorus, nitrogen and sulphur. Because these other nutrients are limited in stubble, and because Australian soils are generally low in these nutrients, the microbes don't have the balanced diet they need to convert the stubble into soil carbon.

Most of the carbon found in crop residues is actually used by micro-organisms in breaking down stubble. About 70% of the carbon decomposed by micro-organisms is transpired and released back into the atmosphere as carbon dioxide (CO_2) gas. This means only around 30% of the carbon from stubble is potentially available to be converted into soil organic matter and without extra nutrients, only a small proportion of this stubble carbon can be converted into soil carbon. This process is illustrated in Figure 1.

Calculating total soil carbon

Measures of SOC can be used to calculate the total amount of total SOM present in a soil. Soil testing laboratories measure the total amount of SOC (including the HOC, POC and ROC fractions) in a sample and apply the following formula:

Soil organic carbon (%) x 1.72 = soil organic matter (%)

Soil testing laboratories may report results as either organic carbon (OC) percentage or as organic matter (OM) percentage. If your soil test reports for OM, then OC levels can be calculated using the formula:

Soil organic matter (%) ÷ 1.72 = soil organic carbon (%)

The ideal soil carbon level for a particular soil is difficult to determine and is the focus of several research studies. In general, soils with an OC level of less than 1% (or a OM of <1.7%) are unlikely to achieve their full yield potential.

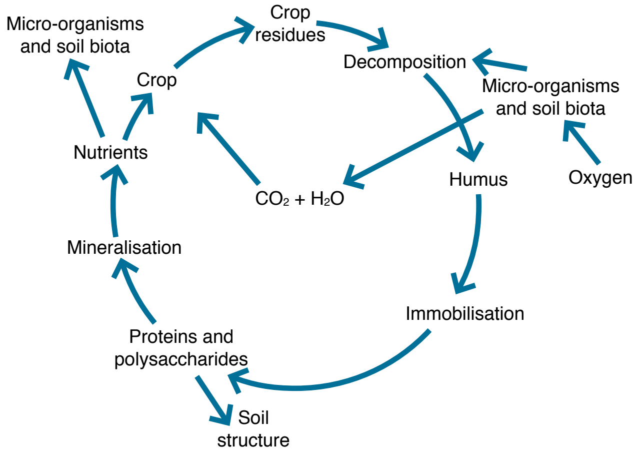

FIGURE 1 The soil carbon cycle

The proportion of nutrients in Humus and wheat stubble

CSIRO researcher, Dr Clive Kirkby, has found that SOM collected from different soils has a consistent ratio of nutrients, which is different to the ratio of nutrients found in wheat stubble. Wheat stubble has proportionately less nitrogen, phosphorus and sulphur than SOM (Table 1).

The role of soil microbes

Numerous studies have shown that stubble-retained cropping systems have more soil microbes compared with non-stubble-retained systems. Microbes enhance nutrient cycling and promote a higher level of aggregate (soil clod) stability, resulting in greater water infiltration and a more resilient soil system.

Laboratory studies have shown that if nutrients are added in the right amounts, it is possible to increase the amount of ***humus*** carbon (the fraction which supports sequestration). Key to this was the finding that the additional nutrients need to be applied soon after harvest to give ample opportunity for microbial decomposition before sowing the next crop.

Measuring soil carbon changes in the Riverine Plains

A lack of field-scale data surrounding this research prompted Riverine Plains Inc to undertake the *Increased soil carbon by accelerated humus formation from crop residues project* funded by the Australian Government's Department of Agriculture Action on the Ground program, to determine whether this concept could be applied in the field.

The project looked at soil carbon accumulation under different stubble management practices including standing, mulched, disced and burnt stubble treatments. It also investigated if post-harvest nutrient (fertiliser) applications affected stubble breakdown and nitrous oxide (N_2O) emissions, a potent greenhouse gas.

Replicated trials were conducted at sites at Rutherglen, Culcairn and Tocumwal, with each stubble treatment receiving a range of post-harvest fertiliser applications during February – March. Yield results were measured at harvest along with soil carbon values for the final two years of the trial.

Key findings

Across all trial sites, and over the life of the project, there were no clear differences in soil organic values that could be attributed to different stubble management practices.

The project identified three factors which were most likely to have limited the potential increase in carbon within the constraints of the field trials:

- **Water**

  Applying fertiliser to stubble during summer can only aid microbial activity if moisture levels are sufficient for microbes to operate. If conditions are too hot and dry, microbes will function more slowly, doing less until conditions improve.

  High levels of soil moisture can also be problematic for microbes, with saturated, low-oxygen conditions inhibiting microbial access and the breakdown of any buried stubble.

  Irrigation also causes increased periods of high soil moisture, which under warm conditions can increase the rate at which carbon breaks down through soil microbial activity. This increased activity can deplete soil carbon reserves and result in larger losses of carbon from the soil to the atmosphere as carbon dioxide gas (CO_2). This makes it more difficult to build, or even maintain, higher soil organic carbon levels under irrigated systems.

- **Scale and consistency**

  Paddock variability must be accounted for when soil sampling. Because the natural variability in soil carbon can be so high in individual paddocks, an enormous change in SOC levels (due to management) may be required to achieve or measure a statistically significant change.

- **Duration**

  Long-term monitoring (10 plus years) would be recommended

Results from the project showed that post-harvest fertiliser applications to promote microbial activity may increase the yield of the following crop in some years, as evidenced by significant differences in yield observed between the nil and 100% post-harvest fertiliser treatment rates in some stubble treatments at some sites. In these instances, part of the additional cost of applying post-harvest fertiliser was recouped through increased yield and, therefore, increased returns. This may not be the case across all years, as rainfall timing and amount will have a bearing on the response to the additional fertiliser applied.

Figure 2 shows results from field work carried out at Rutherglen in 2014, which were typical of results from the project. Low stubble residual nutrient levels and low soil nitrogen levels meant the addition of post-harvest fertiliser was the greatest driver of yield so that grain yield increased significantly with the addition of post-harvest nitrogen fertiliser, but was not significantly different for any single fertiliser rate.

Total soil carbon was also measured at Rutherglen over the course of the project. While some variation in total soil carbon was measured at the Rutherglen site across treatments and time, no statistically significant differences were found over the three years of the project (Figure 3).

Selected soil samples were also collected from the Rutherglen site to measure the amount of particulate organic carbon (POC), humus organic carbon (HOC) and recalcitrant organic carbon (ROC) present. However, there were no statistical differences in carbon fractions between any of the treatments. The proportions of organic carbon in each fraction were also

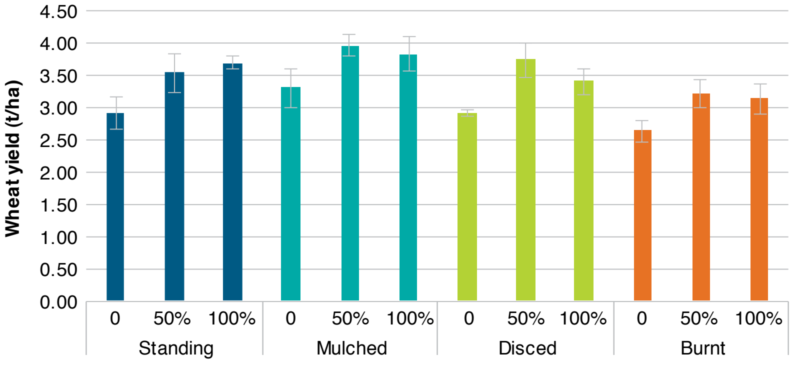

FIGURE 2 Grain yield at the Rutherglen site for the stubble and post-harvest fertiliser treatments during 2014

Note: Post-harvest fertiliser (urea) applied onto stubble residue at 0%, 50% or 100% of 103kg N/ha. Stubble treatments applied February – March. All treatments received 14kg N/ha at sowing and 74kg N/ha in-crop.
The bars are measures of standard error.

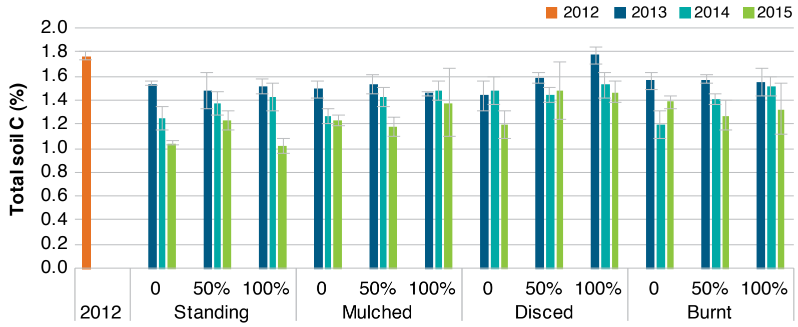

FIGURE 3 Total soil carbon values for the stubble and post-harvest fertiliser treatments at 0–10cm during 2012 (before applying treatments), 2013 and 2014 and in September 2015 (after the project was completed) at Rutherglen

Bars are a measure of standard error. Values are expressed as a percentage (g/100g)

Not corrected for equivalent soil mass.

relatively stable across the treatments, with about 2.1g/kg of POC, 8.6g/kg of HOC and 3.7g/kg of ROC present. Given the variation in results was relatively small, we can conclude that eliciting a significant treatment effect within a soil type or location would take time and major management changes.

The absence of statistically significant results over the three years of the project suggests that longer periods of measurement may be required to determine if applying post-harvest fertiliser might be valid for the Riverine Plains region.

A comprehensive summary of these project results can be found in the publication *Soil Carbon in Cropping Systems*, available from riverineplains.org.au.

Soil carbon and sequestration

From an environmental perspective, carbon sequestration (or long-term storage of carbon) is valued because it can offset greenhouse gas emissions by holding carbon in the soil. However, for carbon sequestration to occur, the carbon must exist in a stable form, such as humus organic carbon (HOC) or Recalcitrant Organic Carbon (ROC). A measurable increase in the HOC fraction at a depth of 0–30cm under specific, international protocols for carbon sequestration must also be observed.

While POC has great value in nutrient cycling and organic matter turnover in soil, it is constantly being consumed and renewed by the soil microorganisms. This prevents POC from accumulating in the soil and as such, it does little to contribute to carbon sequestration.

For carbon sequestration to be viable, farmers must consider the cost of any applied post-harvest fertiliser used to promote microbial activity. Cost analysis undertaken as part of the *Increased soil carbon by accelerated humus formation from crop residues* project showed that in 2014, the cost of additional nitrogen and phosphorus fertiliser required to stimulate microbial decomposition and potentially facilitate humus formation (including spreading) cost $285/ha at Rutherglen, $177/ha at Culcairn and $249/ha at Tocumwal.

If nitrogen could instead be supplied through legume crop fixation, then the cost of applying the additional phosphorus and sulphur could be as low as $60/ha. While this could be more feasible, additional research would be required, including validation of whether inclusion of a legume can contribute to any increase in stable humus organic carbon fraction.

Summary

The *Increased soil carbon by accelerated humus formation from crop residues* project did not clearly demonstrate that more carbon from stubble can be retained through post-harvest fertiliser addition or that soil organic carbon values significantly increased as a result over the three-year trial period.

While there may be some financial gain in managing soil organic carbon for sequestration, there are many greater benefits in continuing to focus on maintaining soil cover and soil organic matter. Even if soil carbon values do not increase, maintaining high microbial activity will have a multitude of soil physical, chemical and biological benefits that go beyond the actual soil carbon value.

Acknowledgements

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The Stubble Initiative involves farming systems groups in Victoria, South Australia and southern and central NSW, collaborating with research organisations and agribusiness to address challenges associated with stubble retention.

The GRDC, on behalf of growers and the Australian Government is investing $17.5 million in the initiative that has been instigated by the GRDC Southern Regional Panel and the four Regional Cropping Solutions Networks that support the panel.

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