More organic matter leads to more soil carbon & better soils

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in a nutshell

- Increasing the amount of organic matter throughput (ie the rate at which organic matter is added to the soil to be broken down and recycled) over a period of several years, will boost soil organic carbon levels
- The research reported in this article suggests that soil carbon can be increased by 0.4% (eg a measurement of 1% would increase to 1.4%) by *increasing* the amount of above- plus below-ground organic matter by 2 t/ha/year, and maintaining this extra input for 10 years
- Across the range of soil types tested, the value of soil carbon can explain approximately 60% of the variation in soil structure (measured as water stable aggregates)
- When soil carbon levels are below 2%, small increases in the carbon level can result in substantial improvements in soil structure (measured as water stable aggregates) – it is reasonable to use 2% soil carbon as a threshold at which optimal soil structure has been achieved
- Higher organic matter systems are likely to result in equal or better yields

The project 'Maintaining the Productivity of Soils under Continuous Intensive Cropping' was initiated in collaboration with the Irrigated Cropping Forum, in response to growers' concerns about the sustainability of their continuous intensive cropping systems, largely due to declining soil structure.

Soil structural decline under cropping systems is an issue that many farmers are familiar with. It is commonly associated with soil hardness, poor germination, restricted root growth, poor water infiltration, reduced water holding capacity, and inevitably reduced yields.

Soil organic carbon has long been considered important in building and maintaining good soil structure. However, a lack of clear understanding of the process and management of organic matter to optimise soil health benefits, while minimising detrimental crop effects, has also led to regions of Australia having high rates of withdrawal from conservation farming. Excessive cultivation and continual removal of organic matter (by burning or grazing crop residues) are the main causes of soil carbon decline. Cultivation is often used to counter the limitations of poor soil structure, but is costly and can exacerbate soil carbon decline by exposing it to rapid breakdown processes. The lack of experimental evidence, under Australian conditions, of the benefits of increasing soil organic matter has also led some scientists to question the appropriateness of advising growers to increase organic matter inputs.

This project has been developing a better understanding of how varying organic matter inputs influences soil organic carbon, and how soil carbon influences other soil physical, chemical, and biological properties, and ultimately crop performance.

Paired paddock comparison

The study of soil carbon dynamics is very difficult because changes in the soil can occur very slowly. Short-term rotation trials simply do not show the long-term effects, and long-term trials are few, and often do not have management systems relevant to current farmer practices.

This project has therefore taken the approach of using farmers' paired paddocks to determine how the management of organic matter affects soil health and crop productivity. Rotational histories and soil measurements were taken from 14 paired paddocks across northern Victoria and southern NSW. Each pair of paddocks consisted of one paddock with higher organic matter input and the other with lower organic matter input. Results in this study are for irrigated cropping systems, so caution should be taken if extrapolating results to dryland systems.

What happened?

Increasing organic matter throughput will boost soil organic carbon levels

Despite the varied locations and rotations for the 14 paired sites, Figure 1 shows that the study found (in all but one site), that the paddock which had the higher organic matter input resulted in a higher soil organic carbon measurement.

Increasing organic matter by 2 t/ha/year for 10 years will add approximately 0.4% to the soil carbon measurement

Although Figure 1 illustrates that all paired sites had increased carbon levels as a result of higher organic matter inputs, the size of the increase is extremely varied. To understand the cause of these different soil carbon levels, the amount of organic matter applied over 10 years at ten of the paired sites has been plotted in Figure 2.

Figure 2 shows that irrespective of the soil carbon values at each site, or the separation between the points at each site, the slope of each line connecting the high (●) and low (■) organic matter input paddocks is very similar at the majority of sites (10 out of 14). This evidence suggests that as a rule of thumb (for these systems): *for every extra 2 t/ha/year of organic matter applied and maintained for 10 years it can be expected that the soil organic carbon measurement will increase by 0.4 of one percent.*

This extra 2 t/ha/yr of organic matter includes the contribution from above-ground parts of the plant plus the below-ground roots. This rate of increase is higher than would be expected from carbon modelling, and is being investigated further.

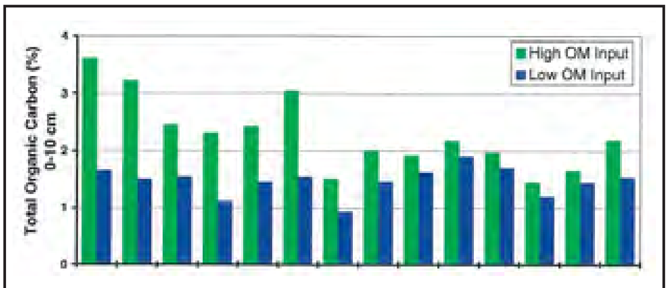

Figure 1: Total carbon in the high and low organic matter (OM) input paddocks at each site.

Across the range of soil types tested, the value of soil carbon can explain approximately 60% of the variation in soil structure

It is important to demonstrate the benefits of increasing soil organic carbon. The growers involved in the establishment of this project were principally interested in knowing how to reduce the problems associated with irrigation, such as poor infiltration and water holding capacity as a result of soil 'slumping'. Figure 3 establishes the relationship between soil carbon and improvement in surface soil structure (measured as water stable aggregates, an indication of the soil's ability to maintain structural integrity when wet). The regression curve provides a good correlation with 60% of the variation in water stable aggregates being explained by the change in soil organic carbon, despite the clay content across the sampled sites varying from 15 to 50%.

When soil carbon levels are below 2%, small increases in the carbon level can result in substantial improvements in soil structure

The relationship in Figure 3 shows that when soil carbon levels are low (<2%), a small increase in soil carbon can result in significant improvements in soil structure. If carbon values have fallen below 1%, soil structural stability is likely to have been seriously compromised. Once soil carbon values reach approximately 2%, further increases in soil carbon (in general) result in negligible further improvement in soil structure. However, having soil carbon values greater than 2% may have other benefits such as increased nutrient supply and improved soil resilience. A more resilient soil structure will protect the soil during periods when organic matter inputs are periodically reduced, which may be required if occasional, strategic operations such as stubble burning or cultivation are required.

Higher organic matter systems are likely to result in equal or better yields

The yield benefits from higher soil carbon values are very hard to measure, and there is very little reported data, even internationally. This is because soil carbon changes occur slowly, especially in the recalcitrant pools, and thus the impacts are difficult to separate from other factors.

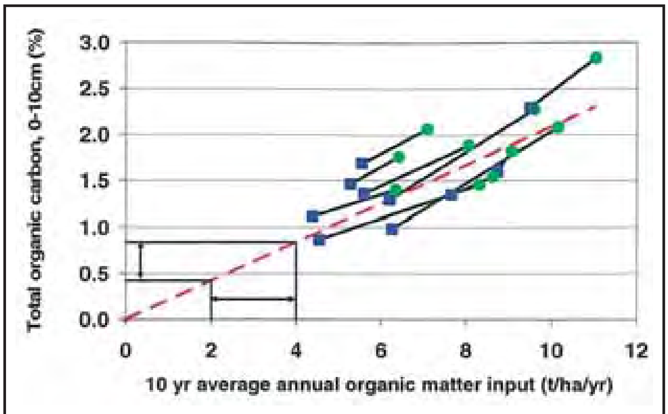

Figure 2: The relationship between the increase in organic matter throughput and the increase in total carbon for selected paired sites (● high organic matter input, ■ low organic matter input) was similar of many of the sites.

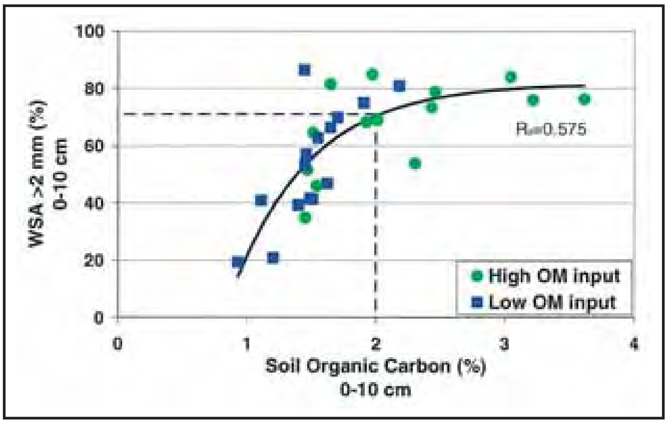

Figure 3: The relationship between soil carbon and water stable aggregates (WSA), showing that at low soil carbon levels (<2%) a small increase in soil carbon can result in significant improvements in soil structure.

However, this project has compared the yield data provided by growers for the paired paddocks. For a range of crops over the past 10 years, the average yields for each high organic matter paddock have been compared to the average yields in the corresponding low organic matter paddock. The results show that the high organic matter input paddocks equal, or outyield, the low organic matter paddocks in most cases (Figure 4). This data constitutes reasonable evidence for growers of the potential financial gains in increasing soil organic matter.

Conclusions and recommendation

The throughput of organic matter drives most soil biological processes, and potentially results in increased soil carbon, better soil structure, higher yields and lower inputs. This study has illustrated that there is a wide range of rotational and management options available to growers for increasing organic matter throughput.

Growers now need to monitor their annual organic matter throughput.

Making it commercial practice

Monitoring each paddock's cumulative organic matter input is an easy way for growers and consultants to monitor improvements in soil health.

This project has provided convincing evidence that it is important for growers to manage their organic matter inputs. However, it is also clear that there are many different management and rotational ways of changing the organic matter throughput, and it is confusing to know what the impact of these changes will be.

There are several carbon models available free of charge (eg Soil Carbon Manager or FullCAM). However these can be difficult to run and the results variable, depending on many soil and climatic conditions. It is suggested that a more useful tool for growers and consultants is a simple carbon calculator developed by the project which provides a graph of cumulative organic matter inputs (Figure 5).

The carbon calculator output can be used to determine the soil carbon benefit of adopting a rotation with higher organic matter input. The soil carbon (%) benefit of a higher organic matter input rotation is the difference between cumulative organic matter inputs at the end of a 10 year period, multiplied by 0.02. For example, for the two rotations shown in Figure 5, the soil carbon benefit of the green rotation after 10 years is (93 – 67) X 0.02 = 0.52% TOC.

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Further information

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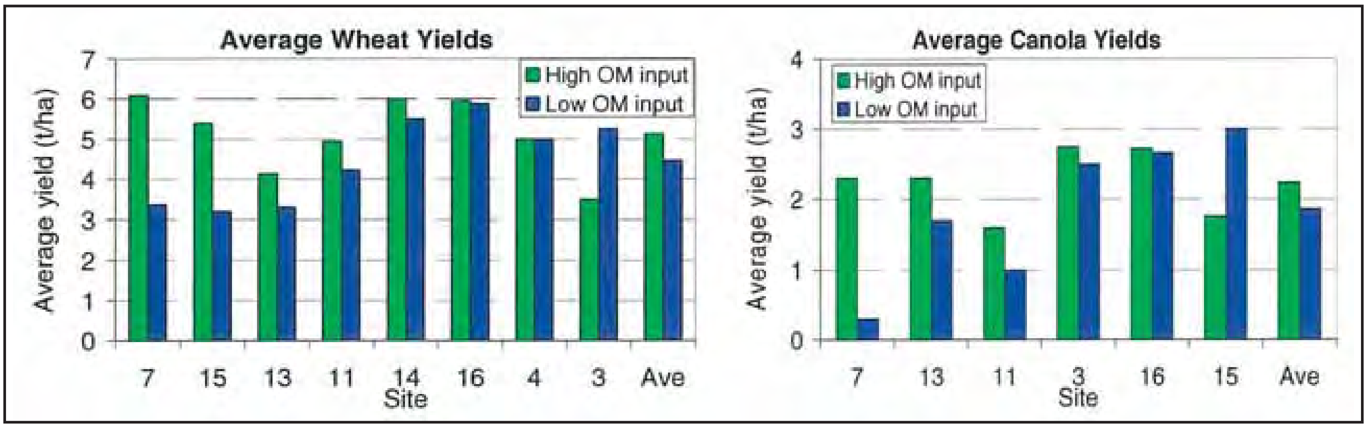

Figure 4: Average yield of high input versus low input paired paddocks for wheat and canola.

Year	Rotation 1 Crop	Rotation 1 Residue Man.	Rotation 2 Crop	Rotation 2 Residue Man.
1	Wheat	Retained	Wheat	Burnt
2	Canola	Grazed	Canola	Grazed
3	Maize	Grazed	Maize	Burnt
4	Canola	Retained	Canola	Grazed
5	Wheat	Grazed	Wheat	Burnt
6	Canola	Retained	Canola	Grazed
7	Wheat	Grazed	Wheat	Burnt
8	Canola	Retained	Canola	Grazed
9	Wheat	Grazed	Wheat	Burnt
10	Canola	Retained	Canola	Grazed

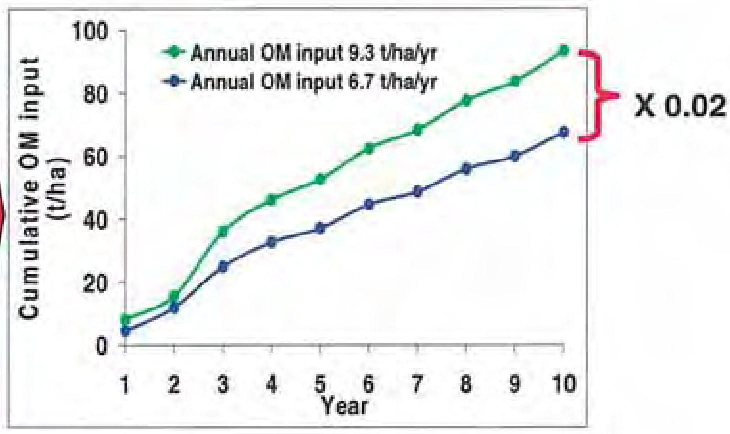

Figure 5: Carbon calculator developed by this project.