Irrigation Research & Extension Committee

2007

Grains Research

UPDATE

GRDC

FOR IRRIGATION CROPPERS

Maintaining the productivity of soils under continuous intensive cropping

Paper prepared by

DR PETER FISHER, COLIN AUMANN, NICK O'HALLORAN, CLIVE KIRKBY, JOHN LACY AND JAN SKJEMSTAD

Ph: 03 5833 5341

Email: peter.fisher@dpi.vic.gov.au

IREC

C/- CSIRO Land and Water, Griffith

Private mail bag 3 Griffith NSW 2680

Tel: 02 69601550 **Fax:** 02 69601562 **Email:** irec@irec.org.au

Take home messages

The following take home messages have been derived from data obtained for a wide range of management practices in the irrigated cropping industry, and at sites in southern NSW and northern Victoria. Although many of these principles are expected to hold true in other farming situations, further validation of the numeric data for other cropping industries is essential. In the results section each of the take home messages is described in a little more detail, and a graph of supporting data is supplied.

- 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 current study suggests that the soil carbon percentage 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. This increase is greater than most carbon modelling suggests.
- 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.
- In future, the role of carbon pools, rather than 'total organic carbon' is likely to offer a greater understanding of how organic matter influences crop production.
- Higher organic matter systems are likely to result in equal or better yields.
- There are a range of rotational and management options available to growers for increasing soil organic carbon. Monitoring each paddock's cumulative organic matter input is an easy way for growers and consultants to monitor likely changes in soil health.

Why do the work

This project was set in the context of two national reports on soil issues facing Australian agriculture, Reeves et al. (1998) and CSIRO (2000), which concluded that soil structural degradation remains, after salinisation, the major threat to the sustainability of agricultural production.

The project 'Maintaining the Productivity of Soils under Continuous Intensive Cropping' was initiated 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.

Approach used

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.

Results

- Increasing the amount of organic matter throughput *will* boost soil organic carbon levels.

Despite the varied locations and different rotations for the 14 paired sites, Fig.1 shows that the study found (in all but one site), that the paddock which had the higher OM input rotation resulted in a higher soil organic carbon measurement. These differences were found in the 0-10, 10-20, and 20-30 cm depth ranges (Fig.2).

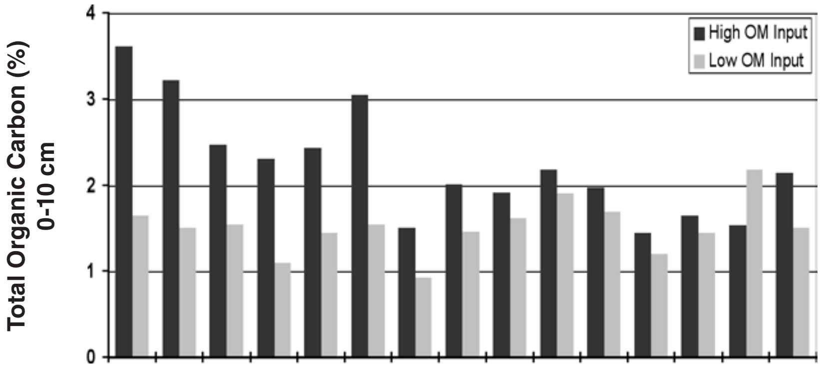

Fig 1 Total carbon in the high & low OM input paddocks at each site.

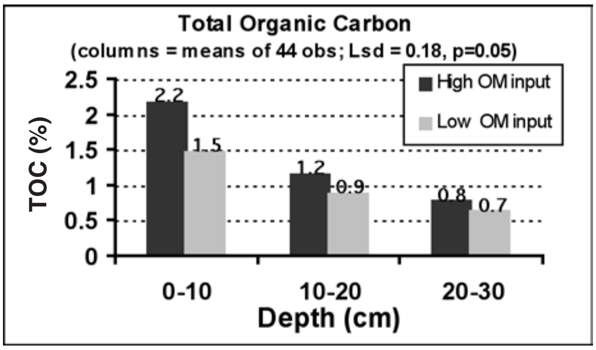

Fig 2 Total organic carbon with depth for all sites.

- *Increasing* the amount of organic matter by 2 t/ha for 10 years will add approximately 0.4 to the soil carbon measurement (in percent).

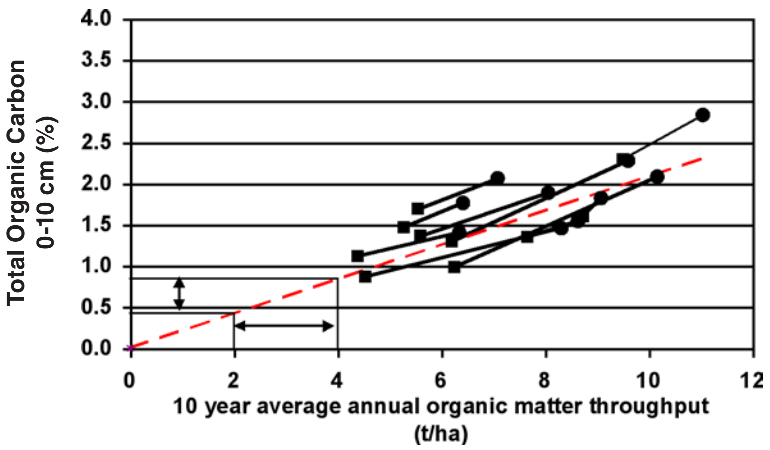

Fig. 3 Relationship between the increase in organic matter throughput and the increase in total carbon for selected paired sites.

Although Fig.1 illustrates that every paired site 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 Fig.3. This figure 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 (λ) and low (ν) organic matter input paddocks at the majority of sites (10 out 14) is very similar. 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 of organic matter includes the contribution from above-ground plus the below-ground roots. This rate of increase is higher than would be expected from carbon modelling, and this is being further investigated.

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

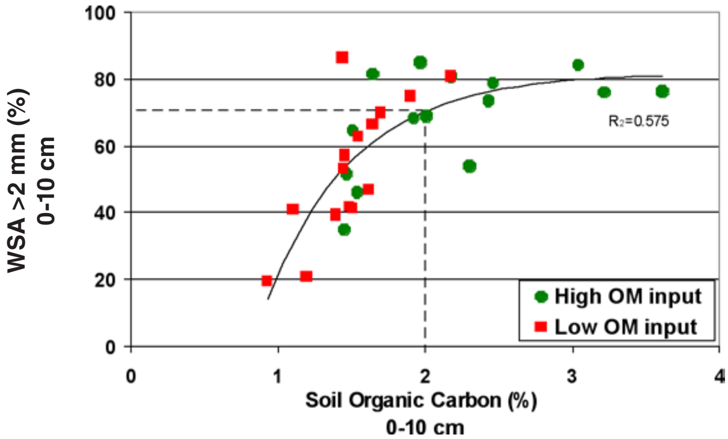

Fig 4 Relationship between soil carbon & water stable aggregates (WSA)

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'. Fig. 4 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 Fig.4 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 of >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.

- The role of carbon pools, rather than 'total organic carbon' is likely in the future to offer a greater understanding of how organic matter influences crop production.

The information presented above is related to the total soil carbon. However, there are many different forms (or pools) of soil carbon. A key difference between these pools is the rate at which they are decomposing, and this also infers different functions within the soil. Although in this study the best relationships have been obtained using total carbon values, as greater understanding is gained on the functions of different carbon pools, and accurate ways are developed to measure different carbon pools, much better predictions will be available about how carbon management influences soil health.

- 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. 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 has been compared to the average yields in the corresponding low organic matter paddock. The results are quite startling, suggesting that the high organic matter input paddocks equal, or out yield the low organic matter paddocks in most cases (Fig. 5). Although not scientific proof, this data does constitute convincing evidence for growers.

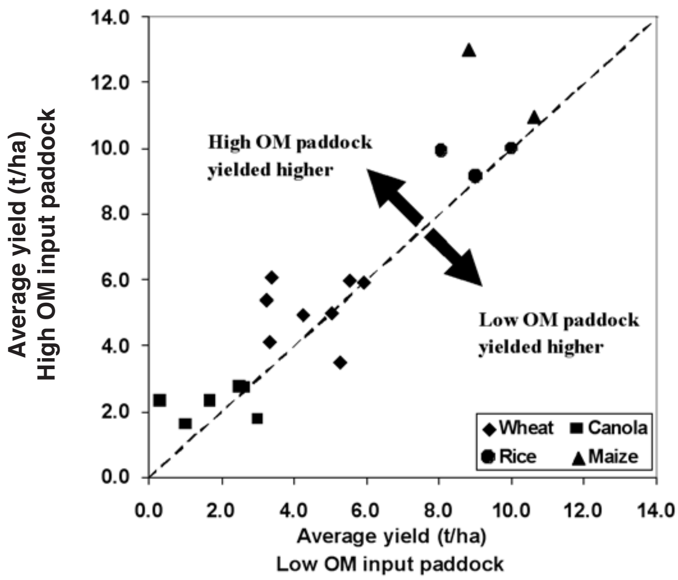

Fig 5 Average yield of high input versus low input paired paddocks

- 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 free carbon models available (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 carbon input (Fig. 6).

Year	Higher input paddock name: South of driveway		Lower input paddock name: Bulloake	
	Crop Rotation	Stubble treatment	Crop Rotation	Stubble treatment
1993	Pasture	grazed	Sunflowers	Burnt
1994	Pasture	grazed	Soybeans	Burnt
1995	Pasture	grazed	Soybeans	Burnt
1996	Pasture	grazed	MaizeGrain	Burnt
1997	Pasture	grazed	Soybeans	Burnt
1998	Pasture	grazed	Wheat	Burnt
1999	Pasture	grazed	MaizeGrain	Burnt
2000	Pasture	grazed	MaizeGrain	Burnt
2001	Pasture	grazed	MaizeGrain	Burnt
2002	Pasture	grazed	Wheat	Removed

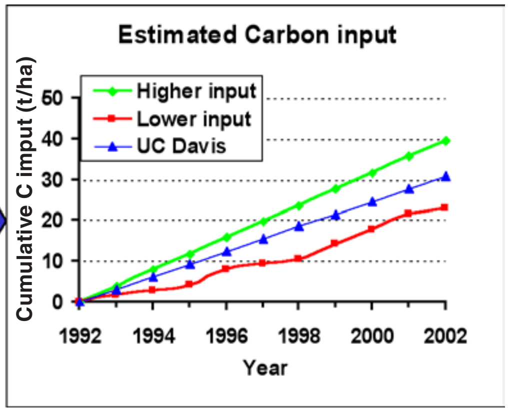

Fig 6 Carbon calculator developed by this project.

Conclusion

The throughput of organic matter drives all soil biological processes, and potentially results in increased soil carbon, better soil structure, higher yields and lower inputs. This study has illustrated that there are 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.

References

Reeves G., Breckwoldt R. & Chartres C. 1998, *Does the answer lies in the soil- a national review of soil health issues*, Land and Water Resources Research and Development Corporation Occasional Paper No. 17/97.

CSIRO Land and Water. 2001, *Scoping study to identify key areas where strategic investigation, research or education is required to retain or improve soil productivity in irrigation areas*, Murray-Darling Basin Commission

Strategic Investigations and Education Program Irrigation Issues Working Group Project I10008.