Speaking of Water and Carbon

By DAVID HANLON

I was recently involved in the launch of our Compost Roadmap Consultancy at Parliament House and was asked by one of the senior politicians if we could show the linkage between compost and water savings. My answer was simply YES, there is plenty of evidence to show that increased organic matter (carbon) increases a soils capacity to hold water. Yet, the direct relationships are often forgotten by a large number of industry and research people alike.

We are seeing an increased interest in increasing soil carbon, not only for water savings but also for nutrient recycling and an improvement in overall soil health. In this article I am only focusing on the water benefits of carbon.

Christine Jones, a pioneer in soil improvement, reminds us that whilst we cannot control soil type or rainfall, we certainly can influence the capacity of our soil to store water. She focuses very heavily on the relationship between soil carbon and water. However, before we get to the relationships we first need to discuss some of the factors that influence water-holding within different soil types and understand the role of carbon.

What do we mean by water-holding capacity?

Water-holding capacity is simply the ability of a soil to keep water within the soil rather than it flowing through the upper soils layers into deeper soil and out of reach of the plant. In so doing a soil is resisting the pull of gravity in much the same way a dish cloth over the sink slows the flow of water down the drain pipe. Whilst the dish cloth provides a physical barrier, within the soil water is retained by surface tension. Just as we see beads of water "holding on" to the surface of a glass of cold water, soil particles similarly "hold on" to water. This is called **surface tension**.

Do all soils have the same capacity to hold water?

Of course not. We all know that sand is a poor holder of water but heavy clays can hold water for a much longer period. Clays have much smaller particles and, in having many more particles per square metre, they have a far greater surface area. Hence they have much greater surface area. As we see in Table 1, the surface area per gram of soil increases from less than 10 sq cm in gravel to more than 8 million sq cm in clay.

We might expect therefore that pure sand would have the lowest water-holding holding capacity whilst pure clay would have the highest ability to hold water however, as David Nagel comments, "surface tension causes an interesting phenomenon in soils. Water will not move out of a small diameter void into a large diameter void until the force of gravity overcomes the surface tension. Therefore, soil with a mixture of large and small particles may have a higher water-holding capacity than a soil made up only of small particles."

Table 1: The relationship between particle size and surface area

Common name	Particle size (diameter in mm)	No of particles (per gram of soil)	Surface area (Sq cm per gram)
Gravel	>2	<90	<10
Coarse sand	1 to 2	90	11
Medium sand	0.5 to 1	720	23
Fine sand	0.25 to 0.5	5,700	45

Fine sand	0.10 to 0.25	46,000	91
Very fine sand	0.05 to 0.10	722,000	227
Silt	0.002 to 0.05	5,776,000	454
Clay	<.002	90,260,000,000	8,000,000
Source: Nagel, D (1977)			

What is soil carbon?

Soil organic carbon is the main way in which soil organic matter is measured within a soil. Generally speaking most of us agree that soil organic matter is one good indicator of soil health.

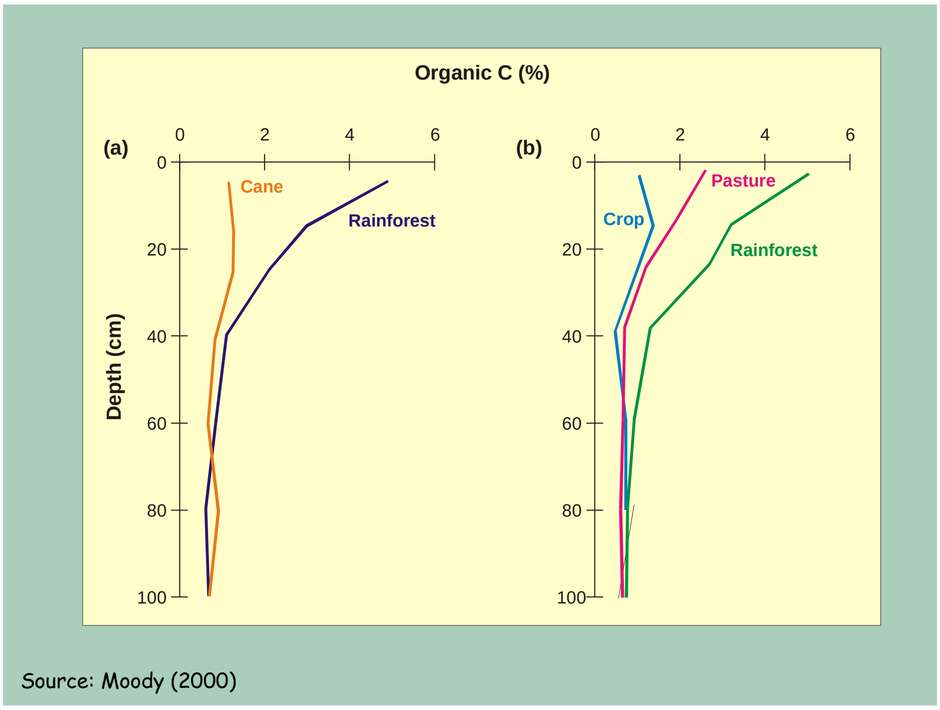
The amount of soil carbon is simply a balance between that carbon which is added to the soil from decomposing plant matter or breakdown of inorganic soil fractions to release carbon less that carbon which is lost through crop/grass removal or volatization.

Why do we need to monitor soil organic carbon?

Monitoring levels of soil organic carbon provides a good measure of the impact of land management on soil health. Changes in soil organic carbon reflect our farm management practices. Chart 1 shows the changes in soil organic carbon from three differing farming systems in Queensland. Graph (a) is from cane farms in the Nambour district whilst graph (b) is from Kingaroy and shows a pasture farming system and a cropping farming system. Both graphs compare the soil organic matter content within the farmed soil and from neighbouring rainforest soils. So what do these graphs tell us? In each case the virgin forest has a soil organic matter content of around 5 percent. After 30 years of continuous farming the soil organic matter content has reduced to around 1 percent in the cane and cropped soil and about 2.5 percent in the pasture soil. If we consider soil carbon to be akin to having capital in the bank, then these two graphs clearly demonstrate that we have been burning up soil carbon at a pretty frightening rate.

There is also the other side of the coin as Christine Jones reminds us: "a 3 percent reduction in soil organic carbon represents almost 400 t/ha extra carbon dioxide (CO_2) emitted to the atmosphere, contributing to increased levels of greenhouse gases and the possibility of climate change."

Chart 1: Change in soil organic carbon over 30 years



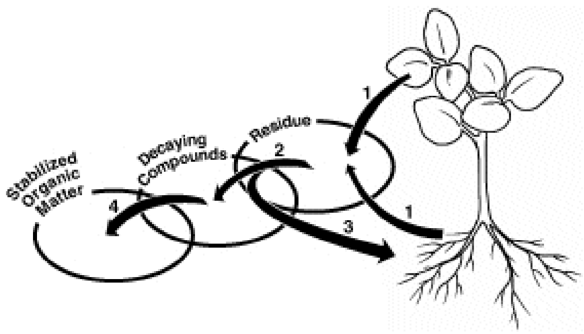
So, what is organic matter?

Seems like an obvious question, however it means different things to different people.

But there is a difference between organic material which is added to soils (ploughed in green manure crops or old crop residues, decomposing prunings, etc) and soil organic matter which forms from the decomposition of this material. Organic material is unstable in the soil and it is important to realize that up to 90 percent of the material we add to the soil can rapidly disappear before it is converted in soil organic matter

For it to become organic matter, it must be decomposed into humus. Humus is organic material that has been converted by microorganisms to a resistant state of decomposition. Organic matter is stable in the soil. It has been decomposed until it is resistant to further decomposition. Usually, only about 5 percent of it mineralizes yearly. That rate increases if temperature, oxygen, and moisture conditions become favorable for decomposition, which often occurs with excessive ground disturbance such as ploughing.

Chart 2: The changing forms of soil organic matter



1. **Additions**. When roots and leaves die, they become part of the soil organic matter.
2. **Transformations**. Soil organisms continually change organic compounds from one form to another. They consume plant residue and other organic matter, and then create by-products, wastes, and cell tissue.
3. **Microbes feed plants**. Some of the wastes released by soil organisms are nutrients that can be used by plants. Organisms release other compounds that affect plant growth.
4. **Stabilization of organic matter**. Eventually, soil organic compounds become stabilized and resistant to further changes.

Source: Anon (2002), *"Organic matter management",* University of Minnesota Extension Service. (http://www.extension.umn.edu/distribution/cropsystems/components/7402_02.html)

How much organic matter is required to increase soil organic matter content?

This is simply a matter of arithmetic to get a feel of what is required.

One hectare of soil to a depth of 15 cm (or 6 inches in the old scale) weighs about 2,200 tonnes. (This will vary according to what scientists call bulk density which the weight of soil per unit volume and the soils bulk density is normally expressed in g cm^{-3} (weight divided by volume). A very compacted soil has a bulk density of 1.4 to 1.6 g cm^{-3} while an open friable soil with good organic matter content will have a bulk density of < 1.0 g cm^{-3}.)

If we take the Nambour rainforest soil in graph (a) above with an organic matter content of 5 percent then we would expect that soil to have about 110 tonnes (2,200 tonnes x 5%) of organic matter. To achieve this amount of organic matter there was somewhere in the vicinity of 1,100 tonnes of organic material to start with.

So, when we are looking at increasing the organic matter content by 1 percent, we would have to be sure that around 220 tonnes of organic material is **converted** (remember not all is converted) per hectare. That is a lot of material. Hence we see why organic matter is far easier to destroy than build up!

What is the relationship between carbon and soil water holding capacity?

With such a lot of organic material required to raise the organic matter content you might ask what is the point and is there a good cost-benefit?   The water benefit is just one of the benefits and, with our increased attention on watersaving capacity, this is pretty important. In Table 2, Christine Jones demonstrates what an increase in organic carbon does in terms of extra water holding capacity per hectare. For example, an extra percent of organic carbon generates 144,litres per hectare water-holding capacity. This amount is over and above the actual water-holding capacity of the soil itself. A 4 percent change increases the water-holding capacity in excess of half a megalitre per hectare. Quite significant changes when you think that is the reduction we have seen in water-holding capacity in the cane and crop soils shown in Chart 1. This amount

Table 2: Changes in soil water-holding capacity with increased soil organic carbon

Change in OC level	Change in OC (kg/m^2)	Extra water ($litres/m^2$)	Extra water (litres/ha)	CO_2 sequestered (t/ha)
1%	3.6 kg	14.4	144,000	132
2%	7.2 kg	28.8	288,000	264
3%	10.8 kg	43.2	432,000	396
4%	14.4 kg	57.6	576,000	528

Note: Based on a soil depth of 30 cm and a soil bulk density of 1.2 g/cm^3
OC – Organic carbon
Source: Jones (2006)

Does this carbon have a value?

The short answer is YES. It has a value in annual water savings and it also has a value as a green house gas emissions control.

Sequestered carbon is a tradeable commodity. It has different values in different markets and the price is subject to market fluctuation. If the CO_2 equivalent was worth $15/tand organic carbon levels were only increased by 0.5% in the top 10 cm of soil this would represent 22 t/ha sequestered CO_2 valued at $33,000 per 100 ha regenerated land (assuming a soil bulk density of 1.2 g/cm^3). As farm managers, the value of carbon in the ground has yet to be included in the national accounting system (it is considered if you plant trees!!!).

Managing your carbon reserve

It is becoming increasingly clear to many growers that managing the carbon reserve within soils is important. Just what methods are put into practice will vary from farm to farm.

The important factor is manage your carbon – it is an important asset that is gaining more value day by day.

References

Anon (2002), *"Organic matter management",* University of Minnesota Extension Service. (http://www.extension.umn.edu/distribution/cropsystems/components/7402_02.html)
Jones. C. (2006), *Soil carbon means water to me!!".* Address to Border Rivers-Gwyddir CMA and Grain & Graze workshops.
Nagel, D (1977), *"Soil Science for Vegetable Producers"*. Extension Service of Mississippi State University, cooperating with U.S. Department of Agriculture.

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