# Soil carbon 101

**By Bill Gardner, WestVic AgServices**

Judging by the amount of misleading statements on this subject, there is a need for a clear explanation of just what makes soil carbon work. It seems that the possibility of soil carbon being worth something is generating some very dodgy schemes for farmers to be sucked into. So here is my understanding of soil carbon.

Soil carbon is a very dynamic entity, and at any time is the result of the rate at which it is being added to soil versus the rate at which it is being eaten by bugs and turned into carbon dioxide. A good analogy is to picture a leaking bucket – a bit of a special bucket in that the rate of leakage is proportional to the amount in the bucket. You have to keep adding organic matter all the time just to maintain the existing level.

It is important to put a few figures in here. A typical soil might contain two per cent organic carbon. For simplicity we will only worry about the top 10 cm of soil as this is where 90 per cent of the action takes place. Soil weighs about 1.4 tonnes per cubic metre. One hectare, to a depth of 10 cm contains 1000 cubic metres of soil. So two per cent of this equals 28 tonnes of carbon per hectare.

This is the size of our leaky bucket.

Remember this number next time someone tries to sell you an organic additive to be applied at a rate of say five kg per hectare.

### Equilibrium carbon levels

Let's make the bold – but probably fairly accurate – assumption that two per cent organic carbon is the equilibrium level for a best practice farming system in which continuous cropping takes place using practices such as stubble retention, zero tillage, controlled traffic and so on.

Now a good crop might yield four tonnes per hectare of grain with a harvest index of around 40 per cent. So total crop production is 10 tonnes per hectare of organic matter (40 per cent carbon).

Research tells us that during the life of the crop, a similar amount of material will be eaten by soil bugs surrounding the roots – that is about 10 tonnes per hectare.

And if we assume similar root mass to shoots, that gives another 10 tonnes, plus the straw (six tonnes). So we end up with an annual input into the soil of 26 tonnes per hectare of organic matter – 10 tonnes of root leakage, 10 tonnes of roots and six tonnes of straw (Figure 1).

The amount of carbon in this will be about 40 per cent giving an annual input of 10.4 tonnes of carbon per hectare.

And because we assumed carbon equilibrium, this gives us an estimate of the rate of leakage from our bucket:

- About 10 tonnes of carbon per hectare or 26 tonnes per hectare of organic matter each year.

So in summary, we have 10 tonnes per hectare of carbon being added each year, which just maintains the level of organic carbon in the soil at 28 tonnes per hectare.

### Increasing carbon levels

Here's a bit of maths – how much do we have to add annually to increase soil carbon levels to 30 tonnes per hectare?

Let's assume the proportion of leakage remains the same, that is 10 divided by 28, or 0.357. Leakage for a 30 tonnes per hectare level becomes 10.71 tonnes per hectare, or 26.78 tonnes of organic matter each year.

In other words, an extra 0.78 tonnes per hectare organic matter added every year will eventually reach a new equilibrium point of 30 tonnes per hectare of organic carbon.

This will probably take 10 to 20 years to happen.

Expressed another way – if organic matter inputs increased by 2.6 per cent, after 10 to 20 years, soil carbon would lift from 2.0 to 2.15 per cent.

### The main carbon 'drivers'

So much for idealised systems where we consistently produce 4 tonnes per hectare crops.

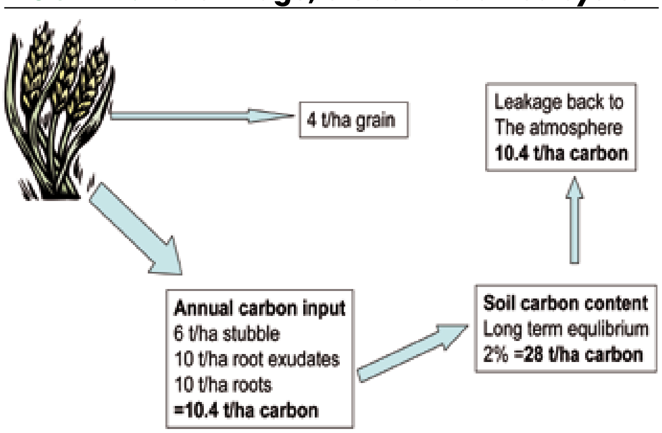
The fundamental driver of organic matter input is climate, especially rainfall. There is a strong correlation between rainfall and soil organic carbon levels.

Vegetation type is important. Systems which intercept more light and make better use of water will generally produce more biomass which inputs into the soil system.

- Forests > perennial pastures > annual pastures > crops

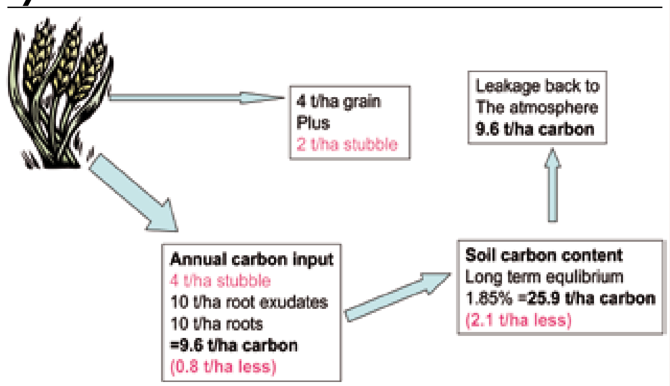
This fundamental truth explains why soil organic carbon levels are generally declining in our cropping systems. The soil is still equilibrating with the change in vegetation

**FIGURE 1: Zero tillage, stubble retained system**




Soil carbon levels require constant addition of carbon just to be maintained. Increased carbon input will slowly cause soil carbon to rise to a new equilibrium level.

**FIGURE 2: Zero tillage, stubble harvested system**




Over 20 years as soil carbon levels come to equlibrium, 40 t of stubble will have been harvested (16 t/ha carbon) while 2.1 t/ha carbon will have been released from the soil. Changes in soil carbon are much less than the cumulative carbon harvested.

**Conservation farming practices only slow the rate of soil organic carbon decline.**

type. For example, Mallee scrub (or Western District pasture) was cleared to grow annual crops.

Annual pastures win out over crops because organic matter removal is lower (for example, three lambs per hectare vs three tonnes of grain removal). Wool production removes even less organic material.

This also underlies why changing crop management (such as retaining stubble) simply slows the rate of soil organic carbon decline. It is an interesting argument that farmers should be paid for this 'Irish' sort of carbon sequestration.

### Some more interesting thoughts

- Organic systems are generally less productive and so will input less carbon into the soil. Try telling an organic devotee that!
- You cannot count the biomass above ground, as in say tree trunks, as they will eventually be consumed and returned to the atmosphere.
- Lower nitrogen inputs increase accumulation of soil organic carbon (the soil carbon is in a form less easily broken down). So legumes are not a good idea?
- Making hay is not good for soil carbon levels.

### Soil sequestration 'logic'

If you follow the logic of soil sequestration of carbon to a conclusion, we have to move to permanent forests or wool production on perennial pastures.

In my opinion, there is very little scope for productive agriculture to argue that it can sequester large amounts of carbon in the soil and save the planet.

At best, you can argue that you can improve your practices so that a less undesirable outcome results after a long period of time – for example by zero tilling and stubble retaining – your equilibrium soil carbon level will be higher than it would otherwise be. Unfortunately it is still likely to be lower than your current levels.

Do not scoff at a farming system where a period of pasture is alternated with cropping – it will result in higher soil carbon levels.

## BUT WE CAN TACKLE $CO_2$

So, having disposed of the myth that productive agriculture can store more carbon in the soil, I will tackle the subject from a different angle and show how agriculture can indeed play a meaningful role in tackling rising carbon dioxide ($CO_2$) levels.

The cause of rising carbon dioxide levels is the burning of fossil plant material – coal and oil. This material was formed by plant photosynthesis which by a freak of nature ended up stored and preserved in a stable form.

We have powered the industrial revolution by digging it up and burning it, thereby pushing carbon dioxide levels back towards where they were in the Jurassic era.

Many red herrings swim in the seas of climate change concern (for example sheep burping) but the base issue is to stop burning fossil plant material.

Coal and oil are highly stable forms of carbon (when buried), and it makes more sense to leave them where they are than the alternative which is to burn them, and invent some process whereby we can capture the $CO_2$ and convert it into a sta-

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ble form and store it in the soil or underground.

Commonsense (and thermodynamics) tell you that you cannot burn a fuel, extract the energy, then capture the $CO_2$ and apply energy to turn it back into a stable form (like the original fuel) – and come out in front.

### So, the big question is:

- Can agriculture provide a replacement for fossil fuels?

In my opinion, that is our main game – capturing sunlight and turning it into organic matter – a replacement for the fossil organic matter we currently burn.

Two issues arise:

- Agriculture's output is required to feed people. Yes, this is correct, but I maintain that there is scope to harvest currently unused biomass and use it for fuel. Straw and forest material spring to mind plus many other by-products.
- It might be argued that burning this organic material will result in an overall decline in soil carbon levels. This is best explained by an example.

Let's say we decide to change our continuous cropping, stubble retained system to a continuous cropping, stubble harvested and burnt system (Figure 2).

In the first 20 years, soil organic levels will decline in line with the stubble being removed which would have otherwise been added to the soil. We saw earlier that adding (removing) 0.76 tonnes per hectare carbon inputs annually would result in about a two tonnes per hectare soil carbon change.

So in the first 20 years, we can substitute our 15 tonnes (20 years times 0.76 tonnes per hectare) of carbon (stubble) for the same amount of coal. That is, we will have stopped 15 tonnes of carbon being burnt as coal, replacing it with 15 tonnes of carbon as stubble. We will have incurred a penalty of two tonnes of carbon released from the soil.

Over the 20 years we are ahead by 13 tonnes of carbon per hectare.

In the next 20 years, no further change in soil carbon takes place, and we are in front by 15 tonnes of carbon. Interesting if you place a value on the carbon of say $50 per tonne.

This is the argument we must somehow put up to the powers that be – forget about soil sequestration of carbon – wrong direction and wonky logic.

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## A NEW INCOME STREAM FOR FARMERS

Selling straw could provide a useful boost to farm income, and the associated activity (windrowing, baling, transport and electricity generation) would provide jobs and turnover in rural districts. If rainfall continues to be erratic, straw production may be a viable option in years when there is insufficient rain to take crops through to a grain harvest.

### Supply

Transport costs must be minimised, so assume a circle 75 km radius with its centre on a regional town, for example Horsham, Nhill or Kaniva in Victoria's Wimmera.

A supply of 100 t/day will be assumed, but note this is quite conservative. Innovations such as comb fronts and chaff harvesting could also increase this supply.

| **Low estimate** | | |
|---|---|---|
| 75 km radius | | 1,767,800 ha |
| % crop | 40% | 707,142 ha |
| % cereal | 60% | 424,285 ha |
| Straw from | 10% | 42,429 ha |
| Yield of straw | 1 t/ha | 116 t/day |
| **High estimate** | | |
| Straw from | 20% | 84,857 ha |
| Yield of straw | 2.5 t/ha | 581 t/day |

### Harvesting and transport costs

This analysis works on costs of $20/ha for windrowing, $24/t for baling, $15/t transport (50 km), and $41/t to the grower. Total costs add to $100/t. Note that the current value of feed grain around Horsham is about $100/t.

### Energy production from the straw

Various options include ethanol production, liquification, hydrogasification, pyrolysis and direct combustion to produce electricity. Replacing fuel such as that required for heating municipal indoor pools has excellent economic returns, but on a large scale, electricity production and selling into the grid is the most realistic option.

Returns accrue from two sources, sale of electricity into the grid and renewable energy credits or RECs.

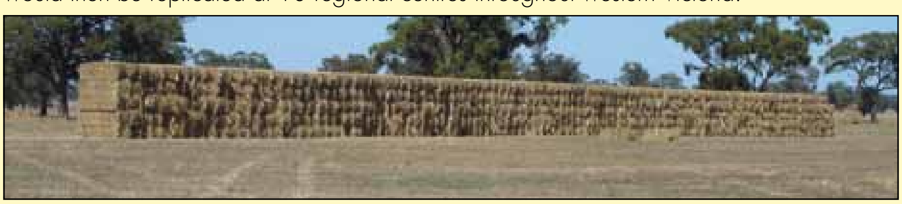
Peak electricity cost is about $0.16/kWhr, and this probably represents the maximum that could be achieved selling into the grid. (Note however that net electricity from domestic solar systems sells at $0.66/kWhr, so perhaps this is not cut and dried)

The other return comes from the RECs which accrue at a rate of 1 REC=1mWhr. These are sold to other generation companies who need to hold sufficient to meet the state government's mandated renewable energy targets. Price is currently about $30/REC, but has been as high as $50. They are expected to fluctuate between $20 and $30 for the next few years.

| | **Low** | **Moderate** |
|---|---|---|
| How much electricity from 1 t/straw/day | .03 mW | .04 mW |
| How much can you sell it for? | $0.16/kWhr | $0.16/kWhr |
| Revenue from 1 t straw sold as electricity | $115.20 | $153.60 |
| Less cost of straw $100/t | $15.20 | $53.60 |
| 100 t straw/day | 3 mW | 4mW |
| Net revenue/day | $1,520 | $5,360 |
| Net revenue/year | $554,800 | $1,956,400 |
| REC generated pa (1 REC=1 mWhr) | 26,280 | 35,040 |
| Value at $25/REC (current $30, range $50–$20) | $657,000 | $876,000 |
| Total revenue per year | $1,211,800 | $2,832,400 |
| **Capital cost** | **$10M** | **$12M** |

NOTES: 0.03 mW/t based on figures from Loy Yang.
$0.16/kWhr current peak power charge by Origin Energy.
$0.66/kWhr is value of net sales from solar systems.

A working group has been formed at Horsham to carry this project forward. The group's aim is to establish a pilot plant of 1mW capacity (cost about $3.5M), demonstrate the business model, and then expand this to 4mW using private investment. This 4mW plant would then be replicated at 10 regional centres throughout western Victoria.



**A group of Western Victorian farmers is investigating the viability of another revenue stream by using straw for energy generation and the subsequent sale of that energy.**