

Farming Carbon

Storing carbon while improving soil health and long-term productivity

A focus on building soil carbon will not only help to improve soil health, it will help to reduce greenhouse gas emissions and potential effects on climate change.

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Improve productivity and reduce greenhouse gas emissions

Soil fertility and soil organic matter (SOM) have declined over 50 to 100 years of cropping in Australia. The graph below shows SOM has decline by around 50% in northern cropping soils. The main impact is less nitrogen mineralised to help produce good crops in high rainfall years.

The increase in carbon dioxide in the atmosphere is partly due land clearing and the decline in soil carbon.

Farming practices which build rather than deplete soil carbon will help reduce greenhouse emissions. They include:

1. Grow high yielding high-biomass crops to maximise carbon input.
2. Eliminate tillage (which stimulates SOM breakdown).
3. Use appropriate fertiliser strategies to maintain soil fertility.
4. Use animal manure as a fertiliser.
5. Pasture leys which include perennial grasses will build SOM.
6. Minimise soil erosion.
7. Maximise crop frequency - avoid long-fallows.
8. Good grazing management
9. Agroforestry

These practices are likely to provide good conditions for soil biota and will improve soil health. Enhancing organic matter will maintain or improve soil structure, soil water balance and the productivity of soils over time.

Good practice can halt the decline in soil carbon and storing carbon in cropping soils will provide a small but useful contribution to lessen the output of greenhouse gases and the potential effect on climate change.

Greenhouse gas emissions can be further reduced by searching for energy savings and managing soils to minimise release of nitrous oxide.

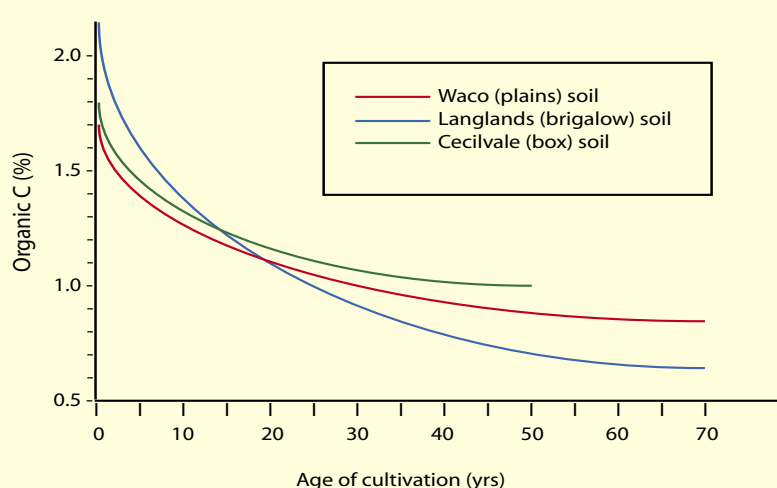
The amounts of carbon involved are likely to be too small in Australia to provide any income from carbon credit schemes, but there is plenty of incentive to build soil carbon if farm profitability improves

Around 1.2 million tonnes of feedlot manure is produced in Australia each year, along with half a million tonnes of pig and poultry manure. Use of this manure will add to soil carbon and boost soil fertility and soil health.

The use of manures and legumes reduces the amount of nitrogen fertilisers used by agriculture and the energy required to produce it, while the nitrogen from these sources is less likely to be lost as nitrous oxide.

Farming carbon is a partial solution to the global warming problem, while at the same time improving soil health and the long term productivity of cropping lands.

Decline in Organic Matter with cultivation



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Soil carbon and Greenhouse gas emissions

Farmland conversion and farming has contributed more to the buildup of carbon dioxide (greenhouse gases) than the use of fossil fuels. Good farming practices can halt organic matter decline and store useful amounts of carbon!

Loss of carbon from farming land

Source	Carbon emission (Gt)
Pre-industrial crop lands	320
Post Industrial (1850-2000)	
- land use conversion	78
- soil erosion	26
- mineralisation of OM	52
Total loss from farm land conversion and farming	476
Fossil fuel use since 1850	270

Source: Lal ; Soils the Final Frontier, Science, Vol 304, June 2004

The clearing of farming land over the last four hundred years has released large quantities of carbon dioxide into the atmosphere. The subsequent decline in organic matter and loss of carbon by other means, such as soil erosion is estimated to emit around 78 giga tonnes of carbon annually.

Lal (see box) says it is possible to reverse the decline of soil carbon.

Farming land has the potential to offset fossil fuel emissions by storing 0.8 gigatons (Gt) of carbon per year, or around 10% of global fossil-fuel emissions.

At the same time this will help achieve the 50% increase in crop yields required between now and 2050 to feed the world. An increase of 1 t. of soil carbon/ha is estimated by Lal to increase crop yield by 20-40 kg/ha. It can be much higher than this on degraded soils where water intake is improved by increasing organic matter.

This is a win-win story - helping to offset some of the fossil fuel emissions of carbon dioxide and helping to improve soil health and crop yields.

In ten long-term studies of no-tillage in the USA an increase of 1.08t/ha/yr of OM (0.6 t/ha C) was measured, compared to a decline of 0.3t/ha/yr where ploughing was used.

This potential to store carbon is higher (in USA) than in most parts of Australia because we have lower rainfall (lower biomass input) and a longer period for mineralisation of OM. In many parts of the US, the soils are too cold for mineralisation of OM over most of winter. In southern Australia conditions are too dry for much of the summer, but in Queensland the conditions are suitable for mineralisation of OM year-round, when there is sufficient moisture in the soil.

Storing Carbon - Carbon credits

In many cropping soils in northern Australia organic carbon is still on the decline. A good starting point is to halt this decline. The potential to build carbon depends upon the capacity to produce good crops (big inputs of carbon) and keep it in the soil by avoiding tillage and managing soil erosion.

Some tillage trials and soil carbon measurements have shown a gain of 0.1-0.2 t/ha carbon per year may be possible in the northern grain belt. While useful and much better than releasing carbon, this is hardly likely to be enough for farmers to receive 'carbon credit' payments. If carbon offsets were valued at \$20/tonne of carbon, then the payments would be \$2-3/ha and likely to be less than the cost of monitoring and administering a carbon credit program.

Nitrous Oxide emissions

As a greenhouse gas, Nitrous oxide (N₂O) is 310 times more potent than carbon dioxide (it reflects more heat back to earth than CO₂) and accounts for more than 25% of agricultural emissions in Australia, according to the Australian Greenhouse Office (AGO).

However, recent studies have shown N₂O losses to be less than expected. Wayne Strong found total N losses at Warra (black soil in Queensland) to vary from 5% in a dry year to 26% in a wet year. At Rutherglen, the annual loss of N₂O in a wheat system was measured at 0.2 kg N/ha, much less than previous AGO estimates.

N₂O losses from the soil mostly occur under wet conditions - when the soil is waterlogged. However, the rain which causes waterlogging will move most of the nitrate N down below the surface layer where denitrification occurs under waterlogged conditions.

Good internal drainage, achieved by zero-tillage and controlled traffic is the main way to reduce N₂O emissions.



Zero-tillage has helped to reverse the decline in soil carbon. USA now has a higher % of zero-tillage than Australia - around 60% of farming land vs 30%. There is still a lot of potential to farm carbon better using less tillage.

Managing Carbon for long-term Soil Health

A healthy soil has good *soil structure*, for optimum water entry and root growth, and good *soil fertility*.

Soil Organic Matter (SOM) decline is directly related to both structure and fertility. As SOM declines, soil structure can deteriorate, increasing runoff and reducing yields. The reserve of nutrients available in the soil declines with SOM. Important questions about SOM include:

- How low can SOM go before crop yields are seriously affected?
- Can we build SOM?
- What is a good level of SOM?

Firstly we should be clear about what SOM is. It is the organic fraction of the soil, exclusive of undecayed plant and animal residues. This is often referred to as humus, except that humus does not include soil microbial biomass.

In practice, SOM includes all plant and animal residues, living or dead microorganisms, charcoal *and* humus. It is measured as soil organic carbon (SOC). To convert SOC to SOM we multiply by 1.724.

A significant portion of SOC can be charcoal, which is almost inert and is not part of the annual nutrient cycle. As SOM declines, charcoal may form an increasingly larger portion of SOC.

Improving soil carbon

Most organic matter (apart from charcoal) is in a constant state of turnover, where it is decomposed and replaced by fresh litter or soil fauna. The level of organic matter in the soil is therefore in a fluid relationship between the amount of carbon being added and the rate of decline.

Farming practices which build SOC, involve growing high yielding crops in rotations, which maximise organic carbon production, in conjunction with a minimum of tillage, to preserve soil organic matter. Pasture leys can build SOM on run-down soils.

In Australia, soils have inherently low SOM, which is related to the rainfall and the low crop biomass production.

Organic carbon levels in soils on the Darling Downs often start around 2% and decline to around 1% after 50-80 years of cultivation. It is difficult to build OC back up, but with good management and high yielding crops, such as grain sorghum, a SOC level of 1.2-1.5 may be possible.

Further west, initial levels of SOC may be high due to the inputs from brigalow scrub or other native vegetation, but it is more difficult to maintain high SOC levels because crop yields and biomass input are lower.

In southern Australia, it may be possible to maintain higher SOC levels in dry cropping areas, because the summer period (when high temperatures can cause rapid breakdown of SOM) is usually dry.

The figure below shows some of the factors affecting the balance (input - losses) of soil organic matter.

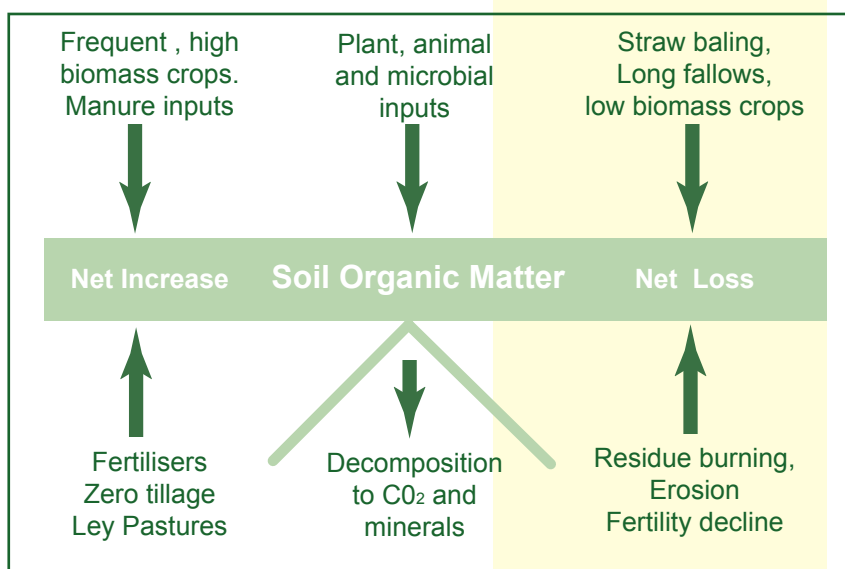
Practices which enhance soil carbon also enhance moisture storage and soil health. If carbon reserves are increasing, this means nutrient reserves are also increasing and extra nutrients may need to be applied.

Organic matter is a key indicator of soil health. It is important for water infiltration and as a reserve of nutrients. It also buffers soil pH. As SOM declines, acid soils will become more acid, while pH increases on alkaline soils.



Good soil organic matter will not only optimise moisture use and crop production, it will also improve catchment health by minimising runoff and erosion, and the soil and pesticides in runoff water.

As soil structure and fertility decline, erosion will increase, setting up a ever increasing cycle of decline.



Best Practice for 'Farming Carbon'

Soil carbon levels will build when high inputs of carbon more than offset the decline.

Contrary to some beliefs, legume residues do not build SOM. Legume residues break down rapidly and enhance breakdown of more resistant SOM.



Feedlot manure can be good value at a cost of \$25/t spread. The N and P content of feedlot manure is currently worth around \$38/t. With the value of potassium (K), manure has a value of \$60/tonne. Sulfur and Zinc can add an extra \$2.00/tonne.

Manure has the extra bonus of building SOM.

1. High yield - high biomass crops

In the northern cropping areas, grain sorghum will produce around 1.5 times the biomass of wheat and twice the biomass of dryland cotton and chickpea. Growing high yielding crops of sorghum will build SOM, while dryland cotton after a long fallow, combined with tillage for pupae busting is likely to deplete it.

2. Eliminate tillage

More than one cultivation a year is likely to result in a continuing decline in SOM. Zero-tillage is essential to building SOM. In conjunction with controlled traffic, zero tillage will minimise compaction. This can enhance moisture intake and reduce surface ponding (from a plough pan) which is conducive to loss of N as N₂O.

3. Maintain soil fertility

A decline in fertility will reduce crop biomass and carbon input. Less ground cover produced by nutrient limited crops may result in less moisture stored and also lower yields. One of the problems of soils with low organic matter is that there is not enough organic N reserve to mineralise extra N for big yields in years with good rainfall.

4. Feedlot, pig and poultry manure

Animal manures can not only add nutrients more cheaply than mineral fertilisers (see table), they also add useful amounts of organic matter.

Around 500,000 tonnes of manure is produced in Southern Queensland each year. With 5 kg of P/tonne of feedlot manure, this is enough to replace P fertilisers (applied at 8kgP/ha) on 300,000 hectares of farmland.

Manure is even more valuable where K is needed as well as N and P. K is more frequently deficient as cultivation gets older. If 200 tonnes of grain is harvested over 60 years of cultivation around 600-800 kg of K has been removed without replacement.

A useful way to manage manure is to apply it as a P fertiliser. If P fertiliser is used at 8 kg P/ha/yr then, 7.5 tonnes of aged manure will apply 50 kg P/ha and last up to 6 years.

5. Pasture leys will build SOM.

A grass-legume pasture can build soil carbon levels by more than 1 t/ha/yr which could lift SOC by 0.05% p.a.

Perennial grasses grow a big root system which contributes to below ground SOM return as well as surface litter.

Excessive tillage should be avoided at the end of pasture phase, or much of the added SOM will be rapidly depleted.

6. Maximise crop frequency

Opportunity cropping with more than one crop per year (on average) is likely to add more biomass and build carbon much better than cropping systems which have long fallows.

Planting wheat as a double-crop after dryland cotton and using feedlot manure can offset some of the potential depletion of SOM, where dryland cotton is grown after a long fallow.

	Fresh Manure ¹		Manure aged ¹		Compost Manure ²		Manure ³ layer hens	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Water content	34%		26%		30%		35%	
Nitrogen (kg/t)	24	16	22	16	24	16	33	21
Phosphorus (P) (kg/t)	7.5	5	9.5	7	10	7	20	13
Potassium (K) (kg/t)	26	17	25	18	25	17	17	11
Value of N+P/t. (wet)	\$33		\$38		\$37		\$61	
Value of NPK/t. (wet)	\$53		\$60		\$57		\$74	
Cost at source	\$4		\$10		\$35		\$25	
Cost with freight of \$10 & spreading \$5/t.	\$19		\$25		\$50		\$40	

Sources: 1: Powell, 1994. Economic Management of Feedlot Manure. Final Report, (average of 93 samples, 17 stockpiled for more than 12 months)
2: Compost data - Environoganics 3: Average from several poultry farms