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Your Economy Changed

Grazing management and building soil carbon

Why soil carbon is important

What is required to capture and store it

Grazing principles

What not to do

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Gold

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Definition

The document is about the value of building soil carbon in grasslands for conventional livestock and cropping production purposes. It has nothing to do with the marketing of soil carbon, should such an opportunity ever emerge. For the purpose of the discussion ‘grasslands’ includes areas where annual grass crops such as oats and millet (ie either cool season or warm season species) are sown and actively managed for grazing.

What is soil carbon?

Soil carbon is the building block of all life. It comes in several forms, but in every case it starts out as ‘soil organic matter’—SOM. SOM is made up of plant material, dung, and the living organisms that are involved in—and die—during the conversion of SOM into *humus*, a process known as ‘humification’.

Humus is the (mostly) stable end result of the biological decay/decomposition of SOM carried out within the soil. Although the litter on the soil surface is crucial for effective decomposition of the organic material below the soil surface, and to the building of soil carbon, for analytical purposes surface litter is generally not regarded as part of the SOM.

During the transition into humus, either from surface litter or from SOM, the carbon passes through several states of varying stability. In some of those states it is prone to rapid movement into the atmosphere. The two most important states are:

1. Very volatile material – known as labile carbon
   Derived from the decomposition of leaves, and manure on the soil surface, and roots sloughed off in the top soil. This material can rapidly volatilise into the atmosphere.
2. Much more stable carbon – known as non-labile or recalcitrant carbon
   The carbon contained in fully formed humus. Once formed, under appropriate conditions this material may remain in the soil for thousands of years.

There is no clear boundary between SOM and pure humus. Humus has no defined shape, and when fully formed and stable it has a dark, jelly-like consistency in the soil. It is dark because it is rich in carbon. Pure carbon is black.

The carbon cycle

The whole of life on earth—that is, absolutely every living thing—depends on the carbon cycle. The carbon cycle (Fig. 1) is the process of birth, growth, reproduction, death and decay. If any aspect of the cycle is damaged then land health is damaged (ie soil borne organisms are depleted), productivity of plants is reduced, and the quality of food that comes from both the plants and animals that eat them is much depleted. Taken to its extreme, all significant life as we know it would perish if the carbon cycle were to cease for any reason.

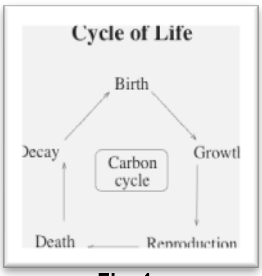

Fig. 1
The Carbon Cycle

By the way, we are all part of the carbon cycle. A carbon cycle is <u>not</u> a lightweight pushbike!

The mineral cycle

The mineral cycle drives the carbon cycle, and there are three parts to it:

1. Plants move minerals from below the soil surface, upwards to above the soil surface, as leaves and stems.
2. Minerals move from above the soil surface back onto the soil surface.
   With trees this is usually natural leaf drop, whilst with grasses the natural processes involve animals who place volumes of dung and urine on the soil surface, or physically trample material. In a few areas of the world this part of the cycle may be completed by termites, or by other small living organisms. When proper natural function is obstructed, this part of the cycle often involves mechanical intervention.

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3. Minerals are returned from the soil surface to below the soil surface, either by dung beetles or by a myriad of micro-organisms and fungi etc.

In an effectively functioning landscape you will want your minerals, including carbon, to cycle and return into the soil rapidly, and certainly once a year or more frequently.

The key to building soil carbon is having an effective mineral cycle on your land. The key to an effective mineral cycle is correctly combining all the tools available, in order to utilise the resources you get for free—rainfall, sunshine and microbes being the key free players.

These free resources are the ingredients that give agriculture a huge, little recognised and almost totally ignored 'unfair advantage' when compared to all other industries in the world.

Incredibly, it is each individual farmer's *own management actions* that allows them to capitalise on this advantage—or to lose it.

Fig. 2
Who has the unfair advantage: Big and bulky or lightweight and nimble?

Indicators that the mineral cycle is functioning on your land

Dung returns into the soil rapidly, standing plants are either green or golden in colour – oxidising leaves should not exist, much trampled litter (plant material) – that is rapidly decomposing, difficult to see the interface between litter and soil

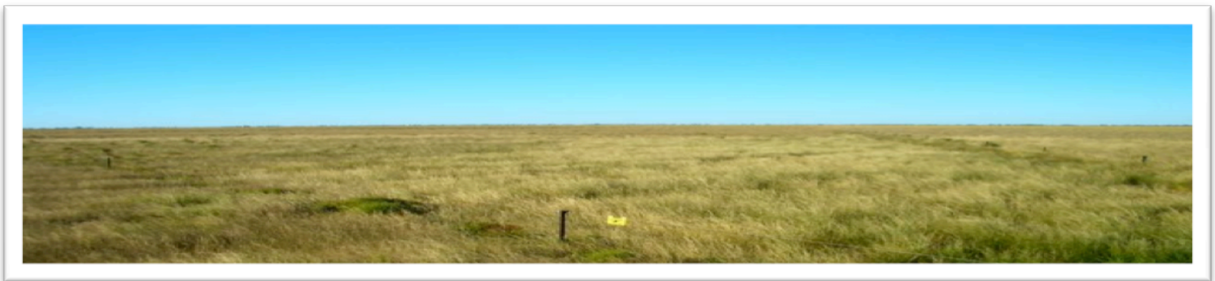
Why soil carbon is important

There are many reasons why soil carbon, the carbon held in humus, is important. They include:

1. The microbial process involved in forming humus causes minerals that were unavailable to plants beforehand to be released from soil particles, and attached to the humus in a plant available form.
2. The greater amount of stable humus there is in the soil, the more rapidly the mineral cycle will function
3. The faster the mineral cycle functions, the greater the productive potential of the plants growing on that land.
4. Associated with this are enormously complex mechanisms that release growth-promoting substances such as humic and fulvic acids, which are thought to play a positive role in supporting the hormonal function of plants.
5. Humus can attach and hold most of its own weight as water, massively improving the effectiveness of the *water cycle*. As a result, growing seasons are extended, and the frequency and intensity of droughts is reduced.
6. During the humification process the microbes and fungi involved secrete various sticky gums and mucillages. These become part of the crumb structure of soil particles, contributing to soil aeration and further facilitating the water and mineral cycles.
7. The dark colour of soils that contain high levels of carbon means that soils are able to warm up more rapidly in the spring, further lengthening the potential growing season for plants, and as a result, overall productivity.

Where do you get it?

The source of soil carbon is nothing short of a miracle. It comes out of the atmosphere.



How do you get it?

The key process is photosynthesis. This is a complex process, but when dealing with plants there are just four principal things to think about: there must be green leaves, atmospheric carbon dioxide, water, and sunlight. The basic equation, and all we really need to understand in order to manage for soil carbon, is this:

$$2n\ CO_2 + 2n\ H_2O + \text{photons} \rightarrow 2(CH_2O)_n + 2n\ O_2$$

In plain language this is

carbon dioxide + water + light energy → carbohydrate + oxygen

The carbohydrate, which is simply stored energy, is where soil carbon comes from, as it is biologically converted into humus. There is no existing (or anticipated) alternative to the *combined processes of photosynthesis and humification* that can create non-labile soil carbon without further external energy inputs and associated expenses. It happens for free.

During photosynthesis a plant removes large amounts of CO_2 from the atmosphere and converts it into plant organic matter – which we know as leaves and roots. The leaves and roots are made of various forms of carbohydrates (for example sugars and starches), as well as proteins, lignins, waxes, complex forms of plant organic acids, and more!

Leaves and roots are the plant's storage mechanism for the all the various forms of energy that are converted during photosynthesis. On a 'dry matter' basis a grass plant is comprised of about 58% the element carbon in all of its various forms. All of the carbon is sequestered from the atmosphere.

In order to store this complex, energetic pool of nutrients, the nutrients must first be moved to storage points in the plant. Plants do this by passing nutrient rich water up and down their structure, through their vascular system.

This is the magic of soil carbon. When the manager of a property decides to make and hold soil carbon, they do so by maximising the opportunities for plants to photosynthesise sunlight, and to move the maximum possible amount of nutrient laden water through themselves, deep into long-term storage in the soil. At this point though, there is not yet soil carbon. What farmers do next represents both the art and the science of land management.

Soil carbon does not happen by accident, but is the outcome of many deliberate decisions.

How do you keep it?

The trick to storing vast amounts of energy is to *rapidly* grow a huge biomass of plant material. Rapid growth depends on there being highly effective ecosystem processes: the *water* and *mineral* cycles, *solar energy flow*, all in conjunction with plants that are, biologically, high *succession* plants.

It's worth noting that a large aboveground biomass of grass plant material cannot be supported by a small root system. There is a natural balance between the two: as plants get bulkier above ground, their roots go deeper and become more massive underground, as the photo of the potted plants in Fig. 3 shows.

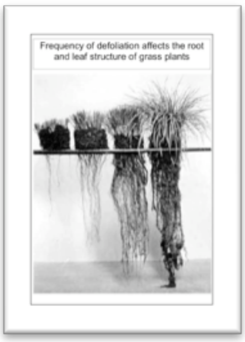


Fig. 3
The effect of above ground biomass on below ground biomass

Plants grow their new leaf and root material along what is known as a sigmoid curve. There is a doubling of a doubling—a compounding effect—just like compound interest. What's more, every human ever born has passed through this process. Here's how it works: We all began life as a single, fertilised cell. Over time we all then divided first into 2 cells, which in turn divided and became 4 cells, then 16 cells, 32 cells, 64 cells, 128 cells, 256 cells, 512 cells, 1,024 cells and so on. Every division or unit of growth doubled our mass. We grew biomass just like a plant. Just like the curve in Fig. 4.

Eventually though, there is no magic pudding! If left to grow without intervention for too long the leaf structure of a plant become tired. The leaf cells begin to lignify and their photosynthetic capacity shuts down. Then, no matter how much sunlight the leaf basks in, no more solar energy can be captured or transported through the plant. You can see this effect as the biomass curve in Fig. 4 peaks, and then declines.

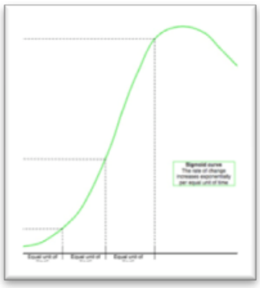


Fig. 4
Sigmoid growth curve

The 'business of agriculture' and soil carbon

The *business of agriculture* is the *capturing, packaging and marketing of sunlight for a profit*. As in all businesses, it's important that management make sound decisions. Decisions that are sound allow farmers to maintain the greatest number of plants in the best possible physical condition, so that each captures the most amount of sunlight energy it can for as many days of the year as is possible.

In grasslands (whether native or sown, annual or perennial) there is a very crucial decision that requires constant review and re-making. That decision, regardless of whether it happens by animal or by machine, is about the *timing of grass harvesting*.

Harvesting the stored energy

The first step in *making* soil carbon is to decide when to harvest some of the energy that has been stored above the soil surface—ie in the leaves. Harvesting the grass is the starting point in making soil carbon.

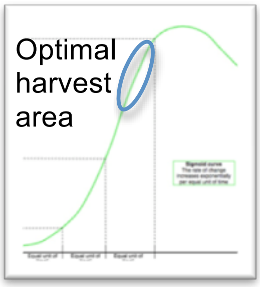


Fig.5
Harvest at the optimal time

Just as a plant cannot sustain a large biomass above ground with only a low root mass in the soil, neither can the reduced post-harvest biomass above the soil surface continue to support the still large biomass below the soil surface. The plant will quickly begin to rebalance itself by shedding or sloughing off roots. You can see this effect in the three left-hand pots in Fig. 3.

The plant kills its own root system for two purposes. Firstly, some of the root energy is translocated back up through the plant to form new leaves: they are the start of new growth. The more severely the plant has been defoliated, the more energy will be required in order to establish its new solar panel — new growth, so more roots will be depleted of their energy in the process. The roots will die, exhausted.

Other roots are killed off simply to re-establish the above and below-ground equilibrium. These too must be rebuilt before the plant is defoliated again.

Composting the stored energy

There are two parts to the composting story:

1. What happens near the soil surface
2. What happens deeper down

What happens near the soil surface

Material on the soil surface is taken back into the soil itself. Dung beetles can play a major part in this, but they are not alone. Other microbes and fungi are also involved. The prerequisite though is a safe home for all of these critters. A safe home for them means a location that is not subject to rapid variations in either temperature or moisture, and where adequate food supplies are constantly available.

Essentially, that means a soil that is well covered with a deep litter of plant material and/or dung, ready for decomposition. This litter: a) is food for the micro-organisms; b) acts as an insulating blanket, stabilising and minimising temperature variations; and c) protects rainfall from evaporation, thus enhancing the effectiveness of whatever rain falls there.

In addition, there will be plant roots that die as the result of grazing or trampling of the above ground material. They too are ready for decomposing or composting by the various micro-organisms that are present.

Some of the carbon is volatile during this transition, and because of its proximity to the soil surface some may escape back into the atmosphere. Any soil surface that is bare is prone to releasing volatile carbons into the atmosphere.

What happens deeper down

This is where things really start to happen. Here, during the root growth phase of the cycle the microbes are sustained by root exudates, which supply them food or energy. Then, as the roots die, following above-ground grazing or trampling, the microbes set to and decompose/compost the dead root material sloughed off and left behind.

Here is the magic: The variety of micro-organisms involved in this process is very diverse. Different species have different purposes and play different roles. Different species are each able to lift specific minerals from soil particles and attach them to the composting material. In addition, close to the soil surface lie other species who remove nitrogen directly from the atmosphere. Nitrogen does not have to come from a bag, or from legumes alone.

Thus as the humus forms it is mineralised, not only from minerals that have been circulating previously, but as the cycle improves, by new minerals that have been taken from the soil particles and added into the circulating pool. In short, soil fertility increases, and because nature is cyclical, the plants, who are designed to access the fertility contained in humus, do so with increasing vigour.

What do I have to change?

The changes are simple, but not easy. The first change happens in the head. You have to believe that what others are already doing, you too can do. Other people are building soil carbon. In order to believe, you must start with a clear understanding of 'why' you will change practices. Perhaps you will need to believe that *'there is a better way to produce food for humans and for the animals who depend on our management for their sustenance.'*

In practical terms, you will need to focus on a single golden rule: 'I must have 100% soil cover on 100% of my farm, for 100% of the time.' Bare soil is public enemy No 1 as it allows, promotes and encourages the carbon you so desperately need in your soil to volatilise straight out into the atmosphere. It is of little value to your plants if it escapes back there.

It is possible to use modern techniques like *pasture cropping* and *no-kill cropping*, that will move you towards the golden rule. Simply put, these techniques (and no doubt there are others) focus on keeping green, growing plants on every hectare, every day. Furthermore they seek to protect those plants (and the organisms that depend on them) from the effects of biocides that might kill either the solar capturing plants or the microbes and critters that depend on those plants for the energy they require to go about forming humus. Biocides include herbicides, pesticides and a great many types of fertiliser that whilst supplying nutrients, are fatal to soil micro-organisms. These fertilisers rely on a hydroponic or acid based process where the roots take nutrients from a volatile solution in the soil rather than from the stable carbon. The two processes are antagonistic to each other.

In addition, you will need to manage the grazing habits of your animals very differently.

Grazing management

In much of the world the natural function that maintained soil fertility for millions of years over billions of hectares relied on three key factors:

1. There were a relatively few herds/flocks that were each very large (big numbers)
2. Those herd/flocks were tightly bunched, with the animals therefore causing considerable disturbance to plants and the soil surface (periodic disturbance); and

3. They were constantly moving, and remained on a piece of land for hours to several days at most (short time whilst plants were exposed to animals)

Under this natural regime any plant material not physically eaten was likely to have been trampled. To a grass plant, trampling is similar to being bitten, as like grazing it initiates root pruning, and is therefore an integral component of grassland health. Both soil surface disturbance and severe plant grazing are desirable circumstances, so long as there is adequate recovery after the disturbance.

Today, much of the world relies on a different, human oriented management approach:

1. There tends to be a great many herds or flocks, each of them relatively small (in western society the farmer chooses to put that bull with those few cows, whilst in pastoral societies each herder chooses to keep his few animals separate from other herder's animals)
2. The many mobs tend to be loosely spread out at low density; thus allowing them to
3. Remain on a piece of land for prolonged periods, often weeks or months, and sometimes years at a time

Nowhere in the world has this human focused combination of practices led to increased long term carbon capture, or to the storage of increased tonnages of soil carbon.

A word of warning about the risks of 'rotational grazing'

It is easy to think that you might go home and "just box some mobs together", and set up some form of rotational grazing. In the short term that will probably give you some good results, but in the end you risk serious damage to your land and finances.

A rotational system becomes a predictable system in an unpredictable environment. You will know you are in a rotational grazing situation of your grazing adheres to any form of rigidity, such as: using a constant speed of movement; consistently moving through the same group of paddocks in the same sequence year after year; grazing individual paddocks at the same time each year; running more or less the same number of animals through the same paddocks year in year out.

In the real world nature does not work in predictable systems, but is dynamic and evolving. This is what is known in science as a 'complex' system. For instance (and as just one of many factors that must be planned for) managers must deal with the reality that plant growth rates dynamically change from fast to slow and vice versa throughout a season and a year. Animals must always move in harmony with those changes. If they don't, overgrazing will occur and carbon loss will be the result.

There are planning procedures that allow mangers to match speed of movement of animals to the growth rates of the plants, and to visually observe and record the changes that are constantly occurring in such dynamic systems, and to alter their management to the evolving reality.

How much carbon is involved?
Let's look at one hectare = 10,000 sq. metres

- Let's consider a soil just 33.5 cm deep (1 foot approx)
- Let's assume bulk density = 1.4 tonnes per cubic metre (range about 0.8 to 1.8)
- Which gives a soil mass per hectare = about 4,700 tonnes
- Therefore a 1% change in soil organic matter = 47 tonnes
- Which yields about 27 tonnes of the element carbon (soil carbon)*
- Which is derived from 100 tonnes of sequestered atmospheric CO_2**

* One tonne of SOM contains about 58% element C. Therefore 47 t SOM x 58% is ~27 t C
** C has an atomic weight of ~12, and Oxygen has an atomic weight of ~16. Therefore one molecule of CO_2 has an atomic weight of ~44 (12+16+16).
To extract 1 tonne of C from the atmosphere 3.66 tonnes of CO_2 must be sequestered (44/12 = 3.66).

27 tonnes of soil carbon x 3.66 tonnes = approximately 100 tonnes of atmospheric CO_2.

In summary

Applying management techniques that deliberately increase soil carbon levels will result in the following: 1) Energy inputs will be lowered; 2) Outputs will cost less per unit produced. It is also likely that productivity will increase, further reducing the unit cost of production.

Energy inputs will reduce as photosynthesis converts the energy of solar radiation into carbohydrates. Carbohydrates are made in part of hydrogen, a massive store of energy (and often suggested as the likely replacement for fossil fuels). Management that deliberately sequesters this free energy will have less need to import costly energy from other sources.

The secrets of grazing management that will build soil carbon

1. Run the maximum size of herd that is practicable over a piece of land for the shortest possible period. This maximises *Animal Impact*
2. Match speed of moves to rate of plant recovery. The 'golden rule' is that in periods of rapid growth you can move more quickly, whilst in slow growth you must move slowly.
3. Whether growth is fast or slow, to avoid *overgrazing* you must ensure animals do not return to a paddock before the plants in it are fully recovered from a previous graze.
4. Match stocking rate to carrying capacity – be slow to build up numbers in the good times, and fast to reduce them when circumstances change
5. Where possible avoid management practices that deliberately or inadvertently kill off microbes and other living organisms.
6. Monitor what is happening on your land. This means photo points AND detailed sites that are assessed at least annually, so that physical changes are noted AND acted upon
7. Soil carbon does not happen by accident. It is the result of meticulous planning. This planning cannot be done in your head, and will require the use of appropriate planning procedures. Learn those procedures. Others before you have learnt the pitfalls, and the information is now widely available.
8. Do not confuse *'planning'* with *'recording'*. They are NOT the same thing. Too often people record what they have done and think they have been 'grazing planning'. Proper grazing planning ensures the animals are where they are required for best performance every day of the year.

Over time, management that deliberately harnesses soil carbon will gain an advantage over management that inadvertently loses soil carbon into the atmosphere.