Carbon, air and water – is that all we need?

Dr Christine Jones
Founder, Carbon For Life Inc.
13 Laurence Ave, Armidale NSW 2350
Christinejones22@aol.com

"The real voyage of discovery consists not in seeking new landscapes but in having new eyes"
[Marcel Proust]

Abstract

With appropriate changes to land management, agricultural soils have the capacity to sequester and store large volumes of carbon, thus improving microbial content, biological activity, fertility, structure, stability, resistance to erosion and ultimately biodiversity, productivity and profitability. Increasing soil carbon can significantly reduce the impact of dryland salinity, reduce sedimentation in rivers and streams, improve water quality, improve air quality and decrease the impact of the greenhouse effect, global warming and climate change.

Soil carbon is the one single, measurable factor that underpins the solution to multiple natural resource management problems. 'Managing the Carbon Cycle' is about turning carbon loss into carbon gain. And 'managing' means just that!!! This is about **healing earth gently, with carbon – and people. Reversing global warming is up to us.**

……………………………………………………………………

Introduction

Imagine how farming would be if all agricultural soils were magnificent. Full of energy. Brimming with life that we could hear, see, smell and 'feel'? When we nourish soils with purpose, passion and pleasure, soil life responds in kind. As above, so below. When you look at your soil, you see your management reflected. We all want soils to be 'healthy'. But where to start?

It is life that gives soil its structure. It is life that provides fertility and balanced nutrition. It is life that retains soil moisture, restoring water balance and reversing the effects of dryland salinity. It is life that retains carbon and nitrogen from the atmosphere and balances the greenhouse equation.

The fundamental question is therefore "how do we get life back into soil?"

CARBON is the basic building block for all life on – and in – the earth. We cannot live without it. Neither can our soils. Vibrant, living soils also require air and water. But these inclusions cannot be retained in the absence of good soil structure, which requires soil carbon. Carbon is the driver for every aspect of soil health and soil function – the MASTER KEY to every door.

Carbon (C) provides the structural basis for thousands of different compounds. It is so common, we take it for granted. We often take hydrogen (H) and oxygen (O) for granted too – but where would we be without H_2O – our precious, life sustaining water? The significance of soil water is becoming more apparent as we lose soil carbon. Low soil water-holding capacity and low levels of soil organic carbon go hand in hand.

An understanding of the role of carbon in soils and of the balance of gases in our atmosphere, is essential to our understanding of life on earth. Atmospheric carbon is an extremely valuable resource. When sequestered in topsoil as organic carbon, it brings with it a wealth of environmental, productivity and quality of life benefits.

Sadly, around 50 – 80% of the organic carbon that was once in the topsoil has been lost to the atmosphere over the last 150 years or so, due to our failure to take care of the earth as a living thing. By inference, degraded soils have the potential to store up to 5 times more organic carbon in their surface layers than they currently hold, provided we **change** the way we **manage** the land.

Anything that causes bare ground results in the loss of organic carbon. If bare earth is produced by chemical or mechanical means, we add insult to injury by burning fossil carbon and adding that to the atmosphere as well.

The rusty tank syndrome

Our thinking about soil is restricted by the terms of reference. We measure factors like pH, phosphorus, calcium and CEC. We add some numbers. Soil pH 5.8, available phosphorus 2 ppm, or 20 ppm or maybe 200 ppm. What do those numbers mean?

We search for more and more detail. Meanwhile, our soils are trying to tell us that things have gone terribly wrong in the engine room. They’re screaming at us to stop and look. When we learn to read the soil, we see decades of history before our very eyes. Communication with landscapes and soils occurs on many levels.

In matters of soil management, we need to learn to avoid the ‘rusty tank syndrome’. This term was originally coined in relation to corporate structures. The livelihood of individuals within corporations is dependent on them maintaining the corporate image and preserving the status quo. If the structure begins to deteriorate, experts are called in from outside to find where the tank is losing water and to ‘fix the leaks’. There’s always someone with a solution to the ‘problem’ – at a price. A rusty spot can be patched up, but soon another will develop and the tank will again begin to lose water. Another expert is called in. More money is spent. The pattern continues. What is really required is a new structure, but there are too many vested interests in maintaining the old one.

The rusty tank syndrome applies equally well to soils. When soils become dysfunctional, that is, not achieving what we’d like them to achieve, we tend to call the experts in to ‘fix the leaks’. The rusty patches manifest as symptoms ranging from compaction, erosion, falling pH, salinity, low fertility and low water-holding capacity, through to declines in vegetation, biodiversity, productivity, crop health, animal health, landscape function, watershed function and eventually, a loss of vitality in rural communities. The never-ending list of problems is served by a plethora of expert opinion and a surfeit of technological fixes.

But, have you noticed, despite the time and money spent, the tank is still rusty? New leaks continue to appear. Alarmingly, many of what are termed ‘improvements’ corrode the tank’s very foundations. Someone forgot to ask ‘does nature approve?’

If we begin at the beginning and build a new tank, we no longer have to continually run around patching up holes. We CAN manage soil life in such a way as to rebuild the building blocks, that is, to restore carbon-rich soils with sound structure, neutral pH, high natural fertility, high water-holding capacity and so much more. From the soil, all else springs. In our mechanised, technologically oriented world, we tend to overlook this extremely significant fact.

Understanding our soils

In the agricultural context, the health of the landscape is determined by how we RELATE to all of the living things in our care. Not just the four-leggeds, but also the life we can’t see. The microscopic workers on the leaves of plants, in the litter on the soil surface and in and around plant roots. The more leaves, litter and plant roots there are, the larger is the workforce of nature’s helpers and the faster we can potentially build new soil. In this unseen world there are thousands of symbiotic relationships and feedback loops. Change one factor and we change them all. All are connected. Every management decision counts.

For these reasons, the simple answer to the question, “carbon, air and water – is that all we need?” is NO.

We need PEOPLE. Inspired, motivated people, working in relationship with each other and with their land to foster an exciting design for a new agriculture. We do not know how this regenerating landscape will ‘look’ – nor do we need to – it will be an evolving work of art. Ecological processes are never static. Our expertise will be directed to understanding process and function in a changing world. Information itself cannot bring about change. ‘Systems’ and ‘recipes’ are doomed to fail.

This is about healing earth gently, with carbon – and people.

Building soil carbon

If organic carbon begins and ends its journey as a gas, carbon dioxide (CO_2), how does it get into soil?

The ‘way in’ for soil carbon is the process of photosynthesis in green leaves. The cheapest, most efficient and most beneficial form of organic carbon for soil is exudation from the actively growing roots of plants in the grass family, which includes many crop plants. The decomposition of fibrous roots is also an important source of carbon in soils. Organic carbon additions are governed by the volume of plant roots per unit of soil and their rate of growth. The more active plant roots there are, the more carbon is added. It’s as simple as that.

Yearlong Green Farming (YGF)

It is important that soil always be covered and that green plants be present for as much of the year as possible to sequester atmospheric carbon and translocate it to soil as organic carbon. This builds organic matter and develops optimum physical and biological conditions, irrespective of agricultural enterprise, environment or landscape position.

Yearlong Green Farming (YGF) has two main principals:-

- roots of actively growing green plants transfer carbon into soil,
- in non-growth periods soil must remain covered to prevent carbon losses.

Variations on the Yearlong Green theme are limited only by human creativity.

One approach is to double crop grain and forage species, so that soil building continues all year. For example, a direct drill winter cereal could be followed by direct drill forage sorghum. The summer forage crop will not only prevent losses of soil carbon, but will be more profitable than maintaining a bare summer fallow.

Alternatively, a summer grain crop could be followed by mixed species winter forage (eg oats, triticale, legumes). Yearlong Green Farming practices are most beneficial when they include livestock, because **strategic** grazing maximises the sequestration of soil carbon.

Let us consider two very practical ‘real life’ examples of Yearlong Green Farming (YGF) practices – one relating to broadacre cropping and the other to grazing.

Pasture Cropping

The quickest and most cost effective way to restore degraded cropland is through a grazed perennial pasture ley. Ironically, the good work is undone when conventional cropping resumes. Thanks to the brilliant insight and visionary thinking of innovators Darryl Cluff and Colin Seis, landholders wishing to build soils through a Yearlong Green technique now have the opportunity to combine annual crops and perennial grasses in the revolutionary ‘one-stop-shop’ land management technique known as Pasture Cropping.

Many of the benefits of Pasture Cropping can be attributed to having perennial grasses and cereals together, side by side in space and time. The ongoing carbon additions from the perennial grass component evolve into highly stable soil aggregates, significantly improving soil structure, while the short-term, high sugar forms of carbon exuded by the cereal crop stimulate microbial activity.

In this positive feedback loop, CO_2 respired by plant roots and soil microbes, slowly moves upwards through the topsoil and increases the partial pressure of CO_2 beneath the crop/pasture canopy, enhancing photosynthetic potential. As money makes money, so carbon makes carbon – but only when the management is right.

Under conventional cropping regimes, the stimulatory exudates from crop roots are negated by cultivation, bare earth and harsh chemicals. Over time, soil carbon levels fall to levels where the soil is essentially ‘dead’ and has little ability to store water. The prime purpose of bare fallows – water storage – becomes self-defeating. Bare soil is also an open invitation to weeds.

Planned Grazing

Soils continually lose organic carbon under set-stocking regimes if insufficient root biomass is present in the soil. This is particularly evident under annual pastures. Forms of grazing management designed to build soil and restore healthy, perennial grasslands are absolutely essential.

Grazing animals, plants, soil biota and soils have co-evolved for over 20 million years, resulting in highly complex – and sensitive – inter-relationships. What are the communication pathways in soil? In what way do living things below ground respond to changes above ground? What are the triggers? How can we incorporate the soil’s needs into grazing management?

Levels of biological activity in soil vary enormously over space and time. They are affected by moisture, temperature, pH, oxygen concentration and the availability of a carbon source (energy). All of these factors are strongly influenced by the way plants are grazed. Of particular interest to this discussion is the supply of carbon compounds to soil biota, in terms of timing, quality and amount.

In a green grass plant, there is generally more nitrogen in the leaves than in the roots and more carbon in the roots than in the tops. When the leaves are removed by grazing, the plant responds immediately to re-adjust this balance. Some carbon (in the form of soluble carbohydrate) is mobilised to the crown for the production of new leaves, some is lost to the soil as pruned roots and some is actively exuded into the rhizosphere (the soil surrounding plant roots) where it can have profound stimulatory effects on soil biota.

If plants are grazed more-or-less continuously, they will have poorly developed root systems and there will be very little carbon available for injection into the soil at each grazing event. The animal-plant-soil ecosystem will decline to a steady-state equilibrium where not much happens other than further deterioration. Many leaks develop because the soil 'tank' is not robust.

When grazing is optimised by ensuring that the most desirable plants (from the animal's perspective) have recovered sufficiently for their root systems to be well established before re-grazing, the net effect of grazing is an increase in soil carbon (energy) levels.

The carbon exuded from the roots of grazed plants stimulates the rhizosphere flora involved in the acquisition and transfer of nitrogen, phosphorus and other nutrients, assisting rapid regrowth of leaves. This enhances energy and nutrient flows. Appropriately managed grazing also stimulates the microbial production of a wide range of plant growth stimulating substances in soils, including natural hormones, enzymes and vitamins.

The optimisation of the grazing process helps to synchronise nutrient mineralisation with plant demands. This reduces losses from the soil ecosystem. Under continuous grazing, particularly in seasonal rainfall environments, the supply and demand for nutrients such as nitrogen rarely match, leading to imbalances and contributing to 'problems' such as soil acidity. It is one of nature's paradoxes that increased levels of soil biological activity not only improve nutrient availability, but also minimise soil nutrient losses and stabilise soil pH.

Managing the carbon cycle

Adding organic carbon to soil is one thing. Keeping it there is another. Topsoil is always in a state of dynamic equilibrium with the atmosphere. Carbon additions therefore need to be combined with land management practices that foster the conversion of relatively transient forms of organic carbon to more stable complexes within the soil.

A net gain of organic carbon in soils is win-win for plants, animals and people. A net gain of carbon in the atmosphere is lose-lose. Our role, as managers of the carbon cycle, is to ensure that as much carbon as possible is returned to soils and as little as possible goes into the air.

Carbon sources and carbon sinks

In bare paddocks, or cropped or grazed paddocks dominated by annual plants, more carbon will move to the atmosphere than is sequestered. That is, the soil is losing organic carbon and is said to be a SOURCE of atmospheric carbon. This adds substantially to the accumulation of the greenhouse gases responsible for global warming and climate change.

In cropped or grazed paddocks managed regeneratively, actively forming topsoils behave as carbon SINKS. That is, more carbon is sequestered than is lost, reducing the level of carbon dioxide in the atmosphere. Getting started in lifeless, compacted soils where the soil engine has shut down is the hard part. The longer we delay, the more difficult it will be to re-sequester soil carbon and re-balance the greenhouse equation.

Carbon and nitrogen

Like carbon, nitrogen moves between the atmosphere and the topsoil in a 'cycle'. The main difference is that the 'way in' for atmospheric carbon is green plants whereas the 'way in' for atmospheric nitrogen is nitrogen-fixing bacteria. Humic substances contain both carbon and nitrogen, thus soils acting as net sinks for carbon are also acting as net sinks for nitrogen. The flip side is that soils losing carbon are losing nitrogen too. Some of this nitrogen loss is in the form of nitrous oxide, a greenhouse gas up to 300 times more potent than carbon dioxide.

Rewarding landholders for farming in ways that build new topsoil and raise levels of soil carbon and nitrogen would have a significant impact on the vitality and productivity of Australia's rural industries, as well as reducing the levels of greenhouse gases.

As a bonus, regenerative farming practices result in the production of food much higher in vitamin and mineral content and lower in herbicide and pesticide residues than conventionally produced foods.

Carbon credits

The capacity for appropriately managed soils to sequester atmospheric carbon is enormous. The world’s soils hold around twice as much carbon as the atmosphere and almost three times as much carbon as the vegetation. **Soil represents the largest carbon sink over which we have control.** Improvements in soil carbon levels could be made in all rural areas, whereas the regions suited to carbon sequestration in plantation timber are limited.

If financial incentives in the form of ‘Soil Credits’ became the prime focus of primary production, farm enterprises such as meat, wool or grain could become of secondary importance as an income source. This would reduce the potential for destructive farm practices and provide a large incentive for ‘greener’ forms of agriculture.

Any farming practice that improves soil structure is building soil carbon. When soils become light, soft and springy, easier to dig or till and less prone to erosion, waterlogging or dryland salinity – then organic carbon levels are increasing. If soils are becoming more compact, eroded or saline – organic carbon levels are falling.

Water, energy, life, nutrients and profit will increase on-farm as soil organic carbon levels rise. The alternative is evaporation of water, energy, life, nutrients and profit if carbon is mismanaged and goes into the air. It’s about turning carbon loss into carbon gain.

Soil formation vs soil loss

The true bottom line for any agricultural practice, is whether soil is being formed or lost. If it is being lost, farming will eventually become both ecologically and economically impossible.

The building of new topsoil depends on us and our future depends on building new topsoil. This is the greatest challenge facing modern agriculture.

Soil loss figures usually assume an average bulk density (weight per unit volume) of around 1.4 g/cm^3. If one millimetre of soil is eroded (about the thickness of a 5-cent coin) it represents about 14 t/ha soil loss. This soil moves into farm dams and into the first and second order streams that feed major rivers, causing and compounding problems all the way to the sea.

If productive soil continues to erode, debates about the optimum enterprise mix, pasture species, fertiliser rate, percentage of trees, riparian buffers or any other 'detail' over which we seem to argue endlessly, are irrelevant. They amount to re-arranging the deck chairs on the Titanic.

Historically, research efforts in the soil science arena have concentrated on reducing the rate of erosion. The Universal Soil LOSS equation (USLE) was devised to estimate losses from various agricultural activities. The concept of building new topsoil is rarely considered. Isn’t it time we developed a Universal Soil FORMATION Equation (USFE) to estimate rates of soil formation?

Healthy groundcover, high root biomass and high levels of associated microbial activity are fundamental to the success of any technique for building new topsoil. Where these factors are present, rates of new topsoil formation of 15-20 t/ha/yr are possible. Many people have built new topsoil in their vegetable or flower gardens. The next step is to learn how to build new topsoil on our farms. If the land management is appropriate, evidence of new topsoil formation can be seen within twelve months, with quite dramatic effects often observed within three years.

Dryland salinity in perspective

When moisture rises in the soil profile, it is often accompanied by salts, which concentrate on the soil surface through the process of evaporation. The key factor in reversing dryland salinity is to always have a small amount of fresh water slowly moving **downwards**, flushing salts from the root zone. Fresh water has a lower density than salt water and will sit above the salt, provided the soil is capable of retaining sufficient moisture for this purpose.

Most areas currently experiencing dryland salinisation were grasslands or grassy woodlands at the time of European settlement, as recorded in explorers journals, settlers diaries and original survey reports from the early to mid 1800s. It is intriguing therefore, that tree clearing in the early 1900s, or later, continues to be cited as the ‘cause’ of dryland salinity.

It is important to view the ‘transient tree phase’ in perspective. There is no doubt that the removal of any kind of perennial vegetation will have an effect on water balance. However, to insist that dryland salinity is the result of tree clearing is a misrepresentation of the facts, particularly when twisted in the current form ‘if we put the trees back, we can solve the problem.’ It is the overlooked understorey, or more particularly, the groundcover and soils, which have undergone the most dramatic changes since settlement. The real cause of dryland salinity is reduced levels of soil biological activity, leading to the loss of soil integrity and water balance.

Soil carbon means WATER – for all

In these days of Climate Change, water is worth its weight in gold. That's why everyone is suddenly talking about 'soil carbon'. Glenn Morris (Morris 2004) extensively researched the water holding capacity of humus. He concluded that within the soil matrix, one part of soil humus can, on average, retain four parts of soil water.

From this we can calculate how water storage in the top 30 cm of soil (roughly the top 12” in old terms) will be influenced by changes in the level of soil organic carbon. The majority of Australian topsoils have bulk densities in the range 1.2 to 1.8 g/cm^3. We will assume a bulk density of 1.2 g/cm^3.

Table 1. Change in the capacity of soil to store water (litres/ha) with changes in levels of soil organic carbon (OC) to 30 cm soil depth. Bulk density 1.2 g/cm^3

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

The calculations in Table 1 show that an increase of 14.4 litres (almost two buckets) of **extra** plant available water could be stored per square metre in the top 30 cm (12”) of soil with a bulk density of 1.2 g/cm^3, for every 1% increase (in absolute terms) in the level of soil organic carbon. That’s 144,000 litres, or about 16,000 **extra** buckets of water that could be stored per hectare, in **addition** to the water-holding capacity of the soil itself.

The flip side is that the same amount of water will be lost when soil carbon levels fall. Low soil moisture and low levels of soil organic carbon go hand in hand.

Soil water storage

Factors that reduce soil organic carbon levels and therefore reduce the ability of soil to store water, include

- Loss of perennial groundcover
- Intensive cultivation
- Bare fallows
- Stubble burning and pasture burning
- Continuous grazing

Most conventional agricultural practices include one or more – or all – of the above. Over the last 50 to 100 years, soil organic carbon levels in many areas have fallen by at least 3% (in absolute terms). This represents the LOSS of the ability to store around 432,000 litres of water per hectare.

One inch (25mm) of rain delivers 250,000 litres of water per hectare, while two inches (50mm) delivers 500,000 litres per hectare.

Greenhouse emissions

In addition to water losses from the landscape, a 3% reduction (in absolute terms) 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. With global warming, rainfall levels could fall even further …. while evaporation rates increase … and degraded soils continue to lose their capacity to hold water … and rivers continue to lose their life-line … the aquifers in the catchment that feed them.

Re-balancing the soil water equation and re-balancing the greenhouse equation have many factors in common. Both processes require soil building, which in turn requires that carbon dioxide from the atmosphere be sequestered in soil as organic carbon.

Reversing climate change at the local, regional and global levels requires a whole of landscape approach. The bottom line is that soils low in humic substances and biological activity cannot effectively store either carbon or water. The carbon goes into the air, adding to the Greenhouse Effect and the water moves off-site, removing soil and nutrients and transforming the most precious of our natural resources into salinity, sedimentation and eutrophication ‘problems’.

Soil carbon, water balance and RIVER HEALTH

The health of terrestrial and riverine ecosystems are intrinsically linked. Rivers and streams exist only because of the catchments that feed them and cannot be regarded as separate entities to those catchments. Healthy, porous topsoils assist with the infiltration of water to transmissive aquifers and provide perennial base flow to rivers and streams, improving water quality, year-round water availability and markedly enhancing general river health.

If the soil has lost it’s porosity due to the structural changes that accompany losses in soil carbon, millions of litres of water move **across** the landscape as run-off – gathering both soil and nutrients – to cause recharge, discharge and sedimentation problems in lower landscape positions.

Yearlong Green Farming techniques that improve the quality and perenniality of groundcover, restoring soil surface condition, porosity, aggregate stability and water balance not only confer production advantages to landholders, but also **ensure that water passes through a series of biological filters on its journey to rivers and streams**.

When the water runs on the top of the ground, or on top of the subsoil, we witness the all too familiar flash flood syndrome, with rivers carrying too much and then too little water, while freshwater aquifers continue to decline. Many once ‘perennial’ streams are now ephemeral, simply due to losses in soil carbon in the catchments that feed them.

The need for change

Increased levels of humic materials in agricultural soils will not only reverse the incidence and severity of erosion, water losses, nutrient losses and dryland salinity – they will optimise farm productivity and significantly improve the quality of our air and water.

The Australian environment is at the crossroads. What are YOU going to do?? Do you want more SOIL or less? More CARBON or less? More WATER or less?

That decision is entirely in your hands.

CONCLUSION

Extraordinary things happen to plants, animals and people when soils are renewed. In any business it’s good business to give the customers what they want. When your soil talks, listen. Healthy soils are not just about carbon, air and water. They are about PEOPLE, including you and me. We’re all in this boat together. Let’s build a good one!!

“The invariable mark of wisdom is to see the miraculous in the common”
[Ralph Waldo Emerson]

……………………………………………………………………………………

Reference

Morris G.D. (2004). ‘Sustaining national water supplies by understanding the dynamic capacity that humus has to increase soil water-holding capacity. *Thesis submitted for Master of Sustainable Agriculture, University of Sydney, July 2004.* Contact gdmorris@hotkey.net.au