SEGments

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Cover Photo: Summer ground cover on regenerated property, 'Dyard', Mollerin, WA. Photograph Ian and Di Haggerty

Rear Cover Photo: Cygnet Park, KI showing native regeneration in 2012, 4 years after planting. Photo: Dept. Water, Environment and Natural Resources

The Scientific Expedition Group is a not-for profit organisation which began in 1984. SEG undertakes several expeditions each year to record scientific information on wildlife and the environment in many parts of South Australia.

A major expedition to conduct a biodiversity survey occurs each year over two weeks. Scientific experts lead volunteers in surveying mammals, reptiles, invertebrates, vegetation, birds and physical geography. The data collected on each survey are archived with the relevant State scientific institutions to ensure they are available to anyone interested in our State's environment.

In addition to the major expedition, a number of trips for the Vulkathunha-Gammon Ranges Scientific Project are organised annually. A long term study of rainfall on the ranges and of water flow in arid-zone creeks is undertaken. All data are supplied to the Department for Environment and Water and to the Bureau of Meteorology and are available for analysis.

SEG conducts four-day biodiversity surveys at eight different sites each autumn and spring in the Heritage Area of scrub on "Minnawarra" farm near Myponga. Data collected are entered into the Biological Data Base of SA. SEG also conducts annual mallee-fowl monitoring over a weekend in the Murraylands.

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EDITORIAL

The Australian National University "Australia's Environment Summary Report 2019" listed Australia's per capita emissions as amongst the highest in the world, at 20.8 t CO_2 equivalent; greater than for the US (1.2 times), EU (2.5 times) and world average (3.3 times). The reasons include the **high per-capita energy use**, the use of polluting coal, and high non-CO_2 emissions.

That some Australian families have little concept of reducing their carbon footprint is made clear in the ABC TV series "Fight for Planet A: Our Climate Challenge" featuring Craig Reucassel. The inefficiencies of draughty houses, inefficient lighting, fuel guzzling cars and high-flow shower heads seem to surprise the families and groups featured in the documentary.

I recall that from around 2003 and through the millennium drought years there was an effort made within the Australian community, **guided by information, subsidies and training** to reduce carbon emissions within our homes and through our transport use; and to address wasteful water practices. A decade and a half ago Australians were urged to consider their own carbon footprint, and a 'calculator' could advise of your personal contribution to greenhouse gases.

In 2003 Herbert Girardet was invited to become South Australia's inaugural 'Thinker in Residence'. The Girardet report "Creating a Sustainable Adelaide" included many recommendations which were adopted by the Rann Government: water storage capacity and five-star energy ratings were mandated on all new homes from July 2006; home subsidies on solar hot water units; and solar panels on 250 South Australian schools and Government buildings, including Parliament House. Girardet's recommendation to increase the planned 1 million trees to 3 million trees (by 2014) was accepted. In SA there was a burgeoning wind power industry and a concerted drive to achieve zero landfill waste.

In the 2007-2013 Rudd/Gillard Governments our Federal leaders took initiatives to reduce greenhouse gas emissions: an emissions reduction scheme was introduced; home insulation was subsidised and long-life fluorescent light globes were encouraged. By 2009, manufacturing in Australia and importation of most incandescent light globes was banned.

Since 2014 Australia has been led by a Coalition Government that I believe has climate change deniers and sceptics wielding power. Under Tony Abbott's leadership the "trainwreck" of regulatory failure on climate change policy commenced (Ross Garnaut's term). Australians in 2020 are still hearing confusing messages from our Prime Minister about Australia's responsibility for global emissions' reduction.

Arguments over the coal, gas and mining industries as the big (and perhaps only) emitters seem embedded in the general psyche, and much of the public argue for more and more renewable energy as the **only way** to address Australia's rising emissions and climate change.

Perhaps the lack of leadership in addressing Australia's responsibilities as a big per capita emitter has led to apathy on the part of a new generation of homeowners to reduce their own footprint through household and transport efficiencies – or even be aware that they have a carbon footprint! Reucassel's documentary indicates that for some householders, their carbon footprint is definitely no longer **front of mind!**

Reucassel estimates that if the 8.2 million households in Australia made similar changes as his guest families (behavioural, transport, food choices, etc.), the result could be a 15% reduction of Australia's 532.5 Mt of carbon emissions measured in 2019.

When thinking about the environmental impact of tonnes of steel, aluminium and concrete; the rare earths and massive volumes of water that are used in building wind turbines, I remembered from 20 years ago a story in David Suzuki's autobiography. In 1988 whilst recording a program, "The Nature of Things", Suzuki interacted with the Kayapo people of the Amazon. A Kayapo leader returned to Canada with Suzuki to advocate for the protection of his homeland in the Amazon. Whilst showing this leader around his hometown in British Columbia, Suzuki was 'stopped in his tracks' when instead of expressing his amazement (and perhaps bewilderment) by the homes, roadways, and power lines that he was seeing, this man quietly said **"and all this comes from the earth"**.

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South Dakota prairies in summer bloom with tasty wildflowers in a multi-species pastures. Photograph Lealand Schoon

REGENERATIVE AGRICULTURE CAN HELP ALLEVIATE CLIMATE CHANGE

Helen Johnson

Introduction

Sequestering carbon in the soil is an effective way of lowering greenhouse gases in the atmosphere. This article describes how our soils can be regenerated enabling them to bury and retain over long periods huge amounts of carbon. Soil carbon boosts biological activity, increases soil, crop and animal nutrients, and improves water infiltration and storage. Soils are regenerated through year-long biodiverse green plant cover; grazing mobs of animals in multi-species forage pastures (with or without crops) using short periods of grazing; and by switching to organic stimulants away from chemical fertiliser (or using minimal fertiliser). Regenerated landscapes require little or no poison application, since biological pest control increases (beneficial insects) resulting in fewer or minimal pests. Food from healthy soils is nutrient rich, to the benefit of human and animal health. All year round plant cover can restore a farm's biodiversity as well as its soil ecology, and farming can once again become profitable! Carbon sequestration in the soil is a very efficient method of removing carbon dioxide from the atmosphere, since one tonne of buried carbon removes 3.7 tonnes of carbon dioxide. Healthy soil also retains moisture and helps to cool the earth's climate.

Coming out of the new organic farming movement in Britain in the first half of the 20th century, one of the important players, Sir Albert Howard (whose knowledge came from the principles of ancient Indian practices) wrote in "An Agricultural Testament" published in 1940, "The main characteristics of Nature's farming … can be summed up in a few words. Mother Earth never attempts to farm without live stock; she always raises mixed crops; great pains are taken to preserve the soil and to prevent erosion; the mixed vegetable and animal wastes are converted into humus; there is no waste; the processes of growth and the processes of decay balance one another; ample provision is made to maintain large reserves of fertility; the greatest care is taken to store the rainfall; both plants and animals are left to protect themselves against disease." This expresses rather beautifully the elements of regenerative agriculture. [1]

Globally averaged concentrations of CO_2 reached 407.8 ppm in 2018, and **total greenhouse gases** are higher when contributions from methane, nitrous oxide, CFCs and water vapour are included. In 2018 the World Meteorological Organisation (WMO) Secretary-General Mr Petteri Taalas said, "The science is clear. Without rapid cuts in CO_2 and other greenhouse gases, climate change will have increasingly destructive and irreversible impacts on life on Earth. The window of opportunity for action is almost closed". https://public.wmo.int/en/media/press-release/greenhouse-gas-concentrations-atmosphere-reach-yet-another-high

Australia's greenhouse gases and IPCC acceptance of soil carbon as negative emissions

In 2018 Australia's total greenhouse gases from electricity production, industry and fugitive emissions from coal and gas production, agriculture, waste, and transport were 550 Mega tonnes (million tonnes) carbon dioxide-equivalent ($MtCO_2e$). In 2012 as part of the Clean Energy Futures package the Gillard Government introduced the Carbon Farming Initiative as a carbon pricing scheme accounting for emissions in the agricultural and land sector.

The CFI is still operating under the Coalition Government. Since 2012, land use and forestry have been counted as a means of sequestering carbon, the amount stabilising in 2018 to around 20 $MtCO_2e$ per annum or 3.6% of total emissions, thus reducing total greenhouse gases in 2018 to 530 $MtCO_2e$. However so much more can be achieved through changed land use practices to increase the amount of **"negative"** emissions! [2]

The International Panel on Climate Change has now accepted carbon capture and storage in soils (at least to 30 cm) in estimating emissions reductions. Recent reports from the IPCC estimate that what has become known as 'natural climate solutions' can provide 37% of the cost-effective reduction in global carbon emissions needed between now and 2030 for a two-thirds chance of stabilizing warming below 2^{o}C. [2] There is still a push by the International Community to have carbon which is stored deeper in soils than 30 cm counted as negative emissions.

Australia's opportunities to reduce emissions

A decade ago the eminent independent British scientist Professor James Lovelock advised: "The most promising and practical way to take the excess carbon dioxide from the air is to ask [the earth] to do it for us." **"**It is much more economic to use the huge and free power of photosynthesis to remove carbon dioxide than to use manufactured energy". Since, across the planet in order to grow food and fibre we have removed extensive forests to create agricultural land (forests which were regulating the climate), it would now seem sensible to manage that land to again regulate the climate. [3]

Innovative farmers worldwide including Australian farmers have changed their farming methods and have witnessed astounding transformations in productivity and **biodiversity**. Based on well-researched and tried experimentation, it is now well known that the speed at which carbon can be sequestered in the soil through photosynthesis is **very fast. There really is no time to waste!**

Extensive lands and woodlands relative to population compared to other developed countries gives Australia a huge advantage for capturing and storing immense amounts of carbon in the landscape.[2] In this article the focus is on the capacity of agricultural land to reduce greenhouse gases, including both carbon dioxide AND water vapour.

Farmland degradation and simplified landscapes

Research over recent decades has been searching for answers to why we have such degraded, unproductive farms. The organic carbon content of most farmed topsoils is now 50-80% less than the original level before intensive agriculture began. As a result our soil structure has deteriorated, resulting in poor water infiltration and lower levels of soil moisture. Whole farms have become unproductive, covered in weeds with hard, compacted soil, producing food and animals with low nutritional value.[4]

As a 2020 Keynote Speaker at a Soil Health Conference in South Dakota, USA, Australian Soil Scientist, Dr Christine Jones, said that what has really changed since the Industrial Revolution is that in much of the world we have hugely simplified landscapes. 30% of the world's cropland has been abandoned in the last 40 years due to soil decline and soil erosion. 90% of the rain that falls evaporates without going through a green plant; causing rising temperatures and drier summers.[4]

Agriculture occupies 38% of the earth's land surface. Through practices such as burning vegetation for land clearing, overgrazing, ploughing, fallowing, over fertilising, using fossil fuels in fertilizers and chemicals and to power farm machinery, industrial agriculture **emits rather than stores** carbon. The released carbon oxidises upon exposure to air escaping as CO_2.[1]

Dr Jones, who implemented the Australian Soil Carbon Accreditation Scheme (ASCAS) in 2007, says "carbon is the driver for every aspect of soil health and function – the MASTER KEY to every door." "Every 2.7 tonnes of carbon sequestered in soil represents 10 tonnes of carbon dioxide removed from the atmosphere".[5]

A major natural event to affect large global systems occurred in the southern hemisphere in the extremely wet year of 2010-2011. Millions of square km of central Australia was covered in mulga, spinifex and wildflowers all pumping millions of tonnes of atmospheric carbon into the ground. "In fact, in that wet year Australia took out of the atmosphere and squirreled into the ground one-quarter of all the carbon produced **globally** through the annual burning of fossil fuels". The records of global CO_2 emissions show a distinct dip for that year, but emissions quickly reversed and trended upwards again in the years 2012-2013 when rainfall over much of the semi-arid zones was half the long-term average, and the vegetation dried out returning carbon to the atmosphere.[1]

The research of Dr Jones and others has revealed that in the simplified landscapes of the Western world, monocultures have replaced mixed plantings, and as a result soil microbe diversity has been reduced to mostly bacteria. Healthy soil is alive, teeming with bacteria, fungi, algae, mites, nematodes, earthworms, ants, spiders, and the roots of plants. Healthy soil has the potential to bury huge amounts of carbon for long periods, depending on the depth in the soil at which the carbon is held; deeper more inert carbon is held for longer (its half-life decomposition can involve centuries to millennia).[1] "Farmers depend on soil for their livelihoods and all of us depend on soil for clean air and water, yet many people have a limited understanding of the profoundly diverse and interconnected ecosystem that is beneath their feet. When we stand on the soil we're standing on the rooftop of another world. … Around 95% of life on land is actually in the soil – and most of it is invisible to the naked eye".[6]

In the 1970s, in an attempt to increase the carbon content of soils there was a change to no-till agriculture in which seeds are directly placed into untilled soil which has retained the previous crop residue. In no-till farming there is minimal soil disturbance. However it turns out that soil disturbance wasn't the issue and in fact there has been almost no improvement in soil carbon through no-till practices. The problem was, with almost bare ground between cropping seasons there was no photosynthesis occurring. Bare ground also leads to increased temperatures and increased evaporation. Another issue was that weeds proliferated and so herbicides were applied, damaging soil microbes.[4]

Experiments have shown that bare ground creates a heat -dome effect. Ambient air at 40ºC in contact with bare ground heats to 60ºC and rises, forcing more hot air in over the bare ground, which in turn heats and rises, causing a heat-dome. In the same experiment, beneath a summer plant cover the ground temperature was measured at 25ºC. Plants keep cool by evaporating water from their leaves, stems and roots.[7] "On land at temperatures above 24ºC rainwater evaporates rapidly enough to leave the land dry in between rainstorms." Meaning that at 25ºC, evaporation beneath a plant cover will be minimal.[3]

Dr Jones explains "the length of time water is held in the soils is a factor in the water balance equation that has changed the most since European settlement." Better land management can reduce the impacts of droughts (and in fact floods). In the agricultural sector, more and more focus is on the importance of water vapour as a potent greenhouse gas with a significant impact on climate change."Whenever landscape is bare, that landscape will not be hydrated. How do we restore a hydrated landscape with higher productivity and a more stable climate?" [7]

Regenerative agriculture

Dr Jones argues we need to get more life back in the soil. Four ecosystems processes provide the means:

- Yearlong green cover to build soil
- Plant diversity
- Biostimulants in place of synthetic fertilizers
- Animal integration

Common appearance of landscapes in south west WA and semi-arid SA which were once covered in flowers and bush tucker perennial plants, even in summer. Photograph Christine Jones

Yearlong green cover leads to soil building

In and article on her website Dr Christine Jones poses the question "Imagine there was a process that could remove carbon dioxide from the atmosphere, replace it with life-giving oxygen, support a robust soil microbiome, regenerate topsoil, enhance the nutrient density of food, restore water balance to the landscape and increase the profitability of agriculture? Fortunately, there is. It's called photosynthesis." [8]

Firstly let's consider how the free power of photosynthesis removes carbon dioxide from the air? Photosynthesis is the process by which the energy of sunlight is transformed into biochemical energy in trees and green plants. Photosynthesis provides the energy for plant cells to convert carbon dioxide and water, into sugars and oxygen. Sugars, **the fuel of all life on earth** are carbohydrates; molecules of carbon, oxygen and hydrogen used by plants as a source of energy. Crucially twenty to forty percent of the carbon fixed during photosynthesis is channelled through plant roots as "liquid carbon" (primarily in the form of sugars) to feed billions of soil microorganisms. These plant root exudates are the **driver** of a healthy soil microbiome, which in turn defend the plant against soil pathogens.

One teaspoon of healthy soil is said to contain more microbes than all the humans on earth. Microorganisms, especially bacteria and fungi, feed off soil carbon (via root exudates) and plant root material, **stabilising carbon in the soil**. These underground microorganisms (that can weigh many more times the plant bulk above ground) produce their own wastes and exudates which become food for plants. An assembly of bacteria, archaea, protists and fungi help with drought and frost-tolerance, reduce soil acidity, salinity and water repellence … and much more. Plant root inputs to the soil build soil carbon 5 to 30 times faster than carbon derived from above-ground biomass.[8]

"Fungi are an essential part of the ecosystem and may consist of 25% of the total biomass on Earth. They don't contain the pigment chlorophyll so they can't make energy from sunlight as plants do. They obtain their food from the substrate on which they live (e.g. wood [plant roots, leaf litter, etc.])… They are the only organism that can break down wood [and plant roots, etc.] so are essential to the decomposition and recycling of nutrients." The chemical composition of wood varies from species to species, but is approximately 50% carbon, 42% oxygen, 6% hydrogen, 1% nitrogen, and 1% other elements (mainly calcium, potassium, sodium, magnesium, iron, and manganese) by weight. (Wikipedia) "Most of the fungus grows and spreads throughout the substrate or host (such as within wood or in soil) as microscopic filaments called 'hypha' individually and 'mycelium' collectively. … Some fungi known as mycorrhyzal fungi form specific mutually beneficial relationships with plants (generally trees) - they provide water and nutrients [derived from decomposed material] directly through hypha and take up sugars". [10]

White mycelium penetrating the underside of bark with the fungal fruiting body above. Photograph A. C. Robinson

Healthy interaction of soil and plants is self regulating according to Dr Jones: the plant can get up to 90% of what it needs through mycorrhizal fungi. Mycorrhizal fungi can bring water to a plant from 20m away. There is also a movement of some free-living microbes from the soil into the plant via plant root tips. This is significant for supplying biological nitrogen via nitrogen fixing bacteria. Specific microbes released into the soil from a germinating seed move back into the plant for its life cycle and go into the next generation of seeds. [7]

Amazingly, actively growing green plants support microorganisms in the creation of well structured friable topsoil. To maximise soil building requires maximum green surface cover from vegetation **throughout the year**.

Only soil microbes build soil! The weathering of rock is a very, very slow process. The building of topsoil, which is altogether different, is a very fast process. Most of the ingredients for new topsoil come from the sun and the atmosphere -- carbon, hydrogen, oxygen and nitrogen. Soil is weathered rock minerals **plus life**; it is a living system which forms a complex web of organisms and microorganisms: fungi, bacteria, pathogens and other organisms. Microbes need to be well organised and well coordinated to build well-structured soil. Plant photosynthesis, plant root exudates, plant diversity and quorum sensing (explained later) are now recognised as constituting the primary pathway for microbes to build soil. [11]

Microbes in the soil go to a lot of trouble to modify the soil to make it favourable for them and the host plants. Glues and gums produced by the soil microbes from carbon build water-stable aggregates which are essential for good soil structure. According to Dr Jones the **aggregate is the fundamental unit of soil function**. These aggregates are full of holes, allowing essential minerals and trace elements released from the soil by microbes to become available to plants making it easier for plant roots to grow and for small invertebrates to move around. To make aggregates soil microbes use **quorum sensing.** In the microbial world, the term quorum sensing refers to density dependent coordinated behaviour that regulates gene expression. In the human example, microbes in our gut can turn our genes on or off. Microbes are 'multi-lingual'; i.e. they communicate species to species, but also they use interspecies communication: fungi, archaea, bacteria all 'talking' to each other. [9]

In an interview by 'The Nation', ex-CSIRO Australian climate scientist Walter Jehne said, "more than 80 percent of a soil's biofertility depends on this surface exposure [through aggregates] rather than on the quantity of nutrients we add as fertiliser."… "As the planet warms, there is more evaporation from the oceans; so we're getting more rain, but it's coming down in extreme, damaging storms … not equally distributed, so along with more extreme flooding there are also more severe droughts. How can we ameliorate these extremes? By rebuilding Earth's soil carbon sponge. About 66 percent of a healthy soil is just space, air—nothing—that creates massive capacity for the sponge to hold water." [12] If farmers cultivate continuously they break up the soil aggregates, making it

Healthy aggregates in clay soil showing crumbly structure, roots and a worm. Photograph Conservation Cropping System Initiative, Indiana

difficult for things that live in that soil to thrive or even survive. Aggregates will break down unless the soil is alive with microbes; the soil then becomes compacted, incapable of storing water.

Dr Jones says "If soil is in good condition, water infiltrates rapidly and is held in the soil profile. Some of this water is used for plant production and some will move downwards through the soil to replenish the transmissive aquifers that feed springs and small streams, enabling year-round, moderated baseflow to river systems. If groundcover is poor and soil water-holding capacity is low, then rapid run-off not only leads to flooding in lower landscape positions, but also takes a lot of topsoil with it. These days it's not just soil, but a heap of chemicals too which end up in [the rivers and the oceans]". [11]

So far nothing that I have described about the soil building process seems to gel with what we dig up from a healthy part of our garden, which is actually **humus**. After the soil microbes, especially fungi, working together have broken down the plant roots, leaf litter, fungi spores, decaying animals (insects and other organisms) to a molecular level (releasing nutrients), the dark organic mostly carbon-based spongy material (polymers of carbon, oxygen, hydrogen and nitrogen) that remains is humus. Humus can hold 20 times its weight in water and can remain in the soil for hundreds of years. Christine Jones says that humus is the Holy Grail. [4]

Plants, soil, microbiology, biodiversity, hydrology and global climate cannot be considered in isolation…all are interconnected. Dr Jones believes that grassland, crop and pasture mismanagement … interfere in efficient photosynthesis.

Plant diversity

How do we get more life into the soil? What supported life in the soil prior to European colonisation in the early 1800's? Plants! Literally hundreds of **different kinds of perennial ground cover plants**. Bush tucker plants were all perennial, i.e. they grew all year round: food for people and animals, and food for the landscape. [7] The grasslands of the North American Great Plains once had enormous diversity with 500 to 700 kinds of plants; 40% grasses, 60% herbaceous flowering plants (forbs), but now grow mostly corn and soybeans. Australian and European grasslands and meadows had similarly diverse plant species. Forbs were much more common than grasses. In Australia in the 1800's, not surprisingly forbs were more palatable to the introduced sheep and cattle and were eaten out within a very short number of years, leaving only grasses. [9]

In healthy regenerated landscapes, polycultures have replaced monocultures and include many different plant groups mixed in with a cover crop: grasses, forbs, herbs and legumes, not simply annual species like clover and ryegrass. Cash crops can be planted (and harvested) with a mix of forage plants, and crop production increases with plant diversity. In southern Australia's Mediterranean hot dry summers, there is not enough rainfall to satisfactorily grow a monoculture, meaning summer crops are not grown and the land remains bare for 6 months of the year. Summer crops thrive in polycultures even in hot dry summers. [7]

A high diversity of plants leads to and supports a high diversity of soil microbes. With low diversity of soil microbes plants become susceptible to pests and diseases, there is poor plant productivity with low nutrient status and reduced water infiltration. It is a completely circular process of destruction; **or of rebuilding**, which starts with yearlong diverse green plant cover leading to rapid building of stable aggregates and rapid soil building. [8]

In Germany a trial over extended seasons and years, the Jena Experiment, showed that plots with 8 and 16 plant species produced a greater plant yield with no added Nitrogen than plots with 1 or 2 plant species with 200 kg added N per year. The soil was deeper with 8 or more different plant species and there were more plant root exudates and more carbon in the soil (21.8% more than low species plots). There was also better root mingling underground (plants support each other and root mingling improves microbe diversity), better soil structure and the soil held more water. The planting plots with 8 and 16 species were better in dry and wet years than the lower diversity species plots, and they survived flooding that lasted for weeks. It is thought that the better soil aggregation in the diverse plots allowed oxygen to infiltrate

A summer field in Alberta, Canada showing a monoculture plot of Triticale (foreground) and a polyculture plot (background) of Triticale in an 8-way mix of sunflowers, oat, radish, various beans and millets . In the mixed plot Triticale plants are growing very well, showing no moisture stress and have headed up with seeds. Both plots are grown under the same conditions. The Triticale grown as a single crop is too poor to harvest. Photograph Christine Jones

the soil helping the plants to survive water-logging. [4]

Polyculture rather than monoculture is seen by Christine Jones as the most significant breakthrough in modern agriculture. [4] "I'm starting to see fields of flowers reappearing around the world as farmers recognise the immense soil and animal health benefits of diverse plant communities. According to the writings of the first European settlers, the South Australian and Victorian grasslands were originally 'carpets of wildflowers'". [13]

Biostimulants in place of synthetic fertilisers

To support and maintain diverse soil micoorganisms, regenerative farmers are turning away from synthetic fertilisers (standard purchased NPK plus trace element fertilisers having soluble and insoluble components), or at least very much reducing their use, and are switching to biostimulants. Examples of biostimulants are worm juice, compost tea (carefully prepared), fish emulsion and seaweed-based liquids, etc. Many are available commercially, but you can make your own. [9]

By applying synthetic fertilisers farmers are interfering with the communication between plants and soil, and soil microbes are being killed. If you pull up a plant and the main root can be seen clearly, then your soil is not healthy. The roots should be surrounded by soil called rhizosheaths containing mycelium (microscopic filaments of myccorhizal fungi). Rhizosheaths help the soil to stick to the roots. [7]

Plants will send signals into the soil to get whatever nutrients they need (nitrogen and phosphorus from the soil as organic N, and organic P, calcium, boron, silicon etc.), and specialised bacteria working in a symbiotic manner with the plant will bring the required nutrients into the plant through the plant root tips. There is a bi-directional flow – carbon going out of the plant, supplying energy to the bacteria, mycorrhizal fungi etc. to source what is needed from the plant root exudates and the soil – and water and nutrients going into the plant. Of all the mineral nutrients, nitrogen contributes most to plant and crop growth. Nitrogen fixing bacteria get nitrogen from the atmosphere and from the breakdown of organic material. In agriculture a most important and efficient symbioses of nitrogen-fixing bacteria and plants occurs in the legume family where the bacteria live in nodules along the plant roots. The symbiotic activities of several nitrogen-fixing bacteria allow Acacias to live in some of the most nutrient-poor soils on the planet. An Acacias' nitrogen fixing contribution helps to regenerate soils.

Inorganic nitrogen fertilisers destroy soil carbon and inorganic soluble phosphorus suppresses the activity of soil microbes. Plant root exudates are influenced poorly by nutrient deprivation (particularly nitrogen and phosphorus). Similarly, fungicides, herbicides, insecticides and pesticides interfere with a healthy soil microbiome, and can destroy many soil microbes. Once the plant's natural resistance to pests and diseases has been interfered with, poisons continually need to be applied to defend the plant, and fertiliser needs to be applied because the plant will not be supported by mycorrhizal fungi. [7]

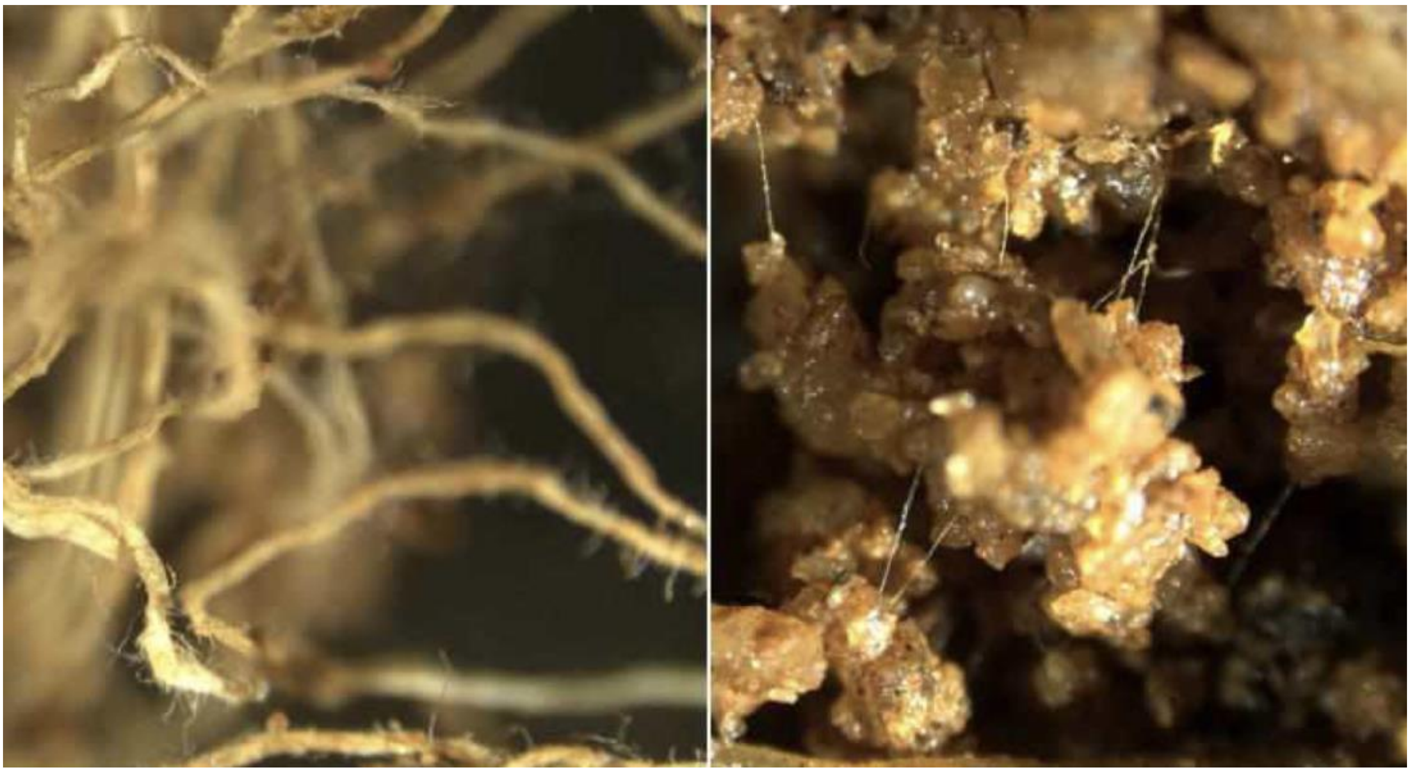
On a Montana ranch, 80 acres were sprayed with a bio-stimulant (fish-oil emollient, molasses, and a small amount of sea salt) and several things happened. "Horses in another pasture smelled the spray and broke through a barbed-wire fence to get to the site and graze the grasses. Then a squadron of dung beetles flew in and went to work so that the horse dung, instead of drying into hard pellets, was buried in the ground by the next day. This typically doesn't happen in a climate that averages [250 to 300 mm] of precipitation per year". [12] (See Dung Beetle article in this edition)

Biostimulants support seed germination, plant health and a healthy soil microbiome. However even biostimulants can be harmful if applied at too high a concentration. I learned that if using multiple biostimulants in an application (e.g. worm juice, compost tea and seaweed extract), each must be applied at one third the normal concentration.

<u>Animal integration</u>

Animals are a vitally important part of the soil building process. Soil building is stimulated even further when plants are in contact with animals as this introduces even greater microbial diversity from saliva, manure, urine, shed hair or wool and particles of shed skin. Photosynthesis is optimised in the presence of animals if appropriately managed.

Soils originally formed in the presence of animals. Critically the effect is greater if animals are bunched up and moving (consider migrating wildebeest in the presence of



Roots of cereal oats in the presence (left) and absence (right) of nitrogen fertiliser. Can clearly see roots on left, but on the right the roots cannot be seen, only healthy rhizosheaths are visible with lots of fungal mycelium and good aggregation. Photograph Phill Lee

Oat plants with healthy rhizosheaths have soil sticking to roots, showing healthy biological activity. Not seen on plant roots with synthetic fertiliser use. Photograph Christine Jones

predators). A revolutionary grazing management system came out of Africa. 'Ted' talks by Zimbabwean Alan Savory are available and worth listening to. At first, I could hardly believe what he said, but I am now convinced of the validity of Savory's method called 'holistic planned grazing'.

In an early international experiment run over 7 years, the Charter Trial, Savory proved by trialling **short duration grazing** with twice the number of cattle compared with traditional grazing, that it was inappropriate management, rather than too many animals that caused land degradation. The practice of grazing livestock continuously in a particular paddock (usually a very large area) known as set-stock grazing is the traditional approach used by pastoralists in Zimbabwe, as well as in Australia. This leaves the land with minimal plant cover and reduced photosynthesis. Within Australia and other parts of the world, the approach of regenerative grazing is to create many small paddocks and to move stock off each paddock after a few days with long resting periods (maybe months) between re-grazing. Stock animals graze in diverse plantings and crops are sown in the same paddocks.

Seminal research in the 1990s by Dr Jones and native plant botanist Dr Judi Earl led them to conclude that "the true causes of degradation of landscape function were not cloven hooves but the mouths of livestock". This grazing of pastures for too long and eating vegetation too low, leads to a cascading effect of destroying too many green leaves, thereby starving the energy production system, and killing too many roots. This degrades the water cycle - infiltration and storage- with associated destruction of soil life and the collapse of nutrient cycling. "Grasslands are distinctive in that they require active management. To not act is to fail". [1]

An amazing success story

On Colin Seis' regenerative farming property 'Winona' in central NSW, sheep are integrated with pasture cropping, optimising production of both while improving soil structure and fertility. From the 'Winona' website https://soilsforlife.org.au/winona-pasture-cropping-the-way-to-health "Sheep are managed in two main mobs of 2000 head and rotated around 75 paddocks in a time-control rotational grazing technique. Introducing time-control grazing necessitated a denser pattern of fencing to increase the number of paddocks from 10 to 75. A central laneway provides an efficient way to move sheep around the property. Over 70 small dams supply stock water as there are no creeks or rivers on 'Winona'. These dams have high water levels and are maintained mainly through lateral underground flow. The combination of the soil type and maintaining a complete groundcover ensures that all rainfall infiltrates". [14]

In a Meat and Livestock Trial in 2020 on 'Winona', 228 Merino lambs raised in a multi-species crop (barley, field peas, Faba beans, forage brassicas, tillage radish and turnips) yielded twice the lamb weights with double the profits of lambs raised in a barley crop alone. [15]

On 'Winona' soil tests have been conducted every 4 years since 2008 to measure soil carbon to a depth of 60cm in the same paddock. The area tested is an average paddock which is managed the same way as the rest of the property, so it can be assumed that the rest of the 800 ha property would average the same results. Results are not yet available for 2020. The management of the paddock from 2008 has been holistic planned grazing with a 3-month plant recovery period. In 2009 and 2011 the paddock was seeded with oats and from 2015 Colin has planted a multi-species pasture crop.

Colin says it is interesting to note that the carbon at 1-10 cm depth has not changed very much, but the deeper levels of 20 to 60 cm have shown a significant increase in carbon. This is most likely due to the deep roots of the native perennial grass species which have come back, and the root exudates from the pasture cropped cereal and multi-species crops. [16]

The increase in soil carbon over eight years is 33.95 tonnes per hectare, an average of 4.24 tonnes per hectare per annum (although the rate has reduced gradually over the 8 years: average 5.57 t/ha/a in period 2008-2012 and average 2.92 t/ha/a over 2012-2016). Taking the average annual rate of increase of carbon as 4.24 t/ha/a means there has been a reduction of 15.56 tonnes CO_2e per ha per year (using factor 3.67).

At Colin Seis' rate, to remove 530 Mt CO_2e (Australia's total greenhouse gases in 2018) using regenerative agriculture would require 34 million hectares. It would take 34,000 properties of 1000 hectares to remove all of Australia's greenhouse gas emissions. The area of cropping and pasture grazing land in Australia in 2016 was estimated by the

Australian Bureau of Statistics to be 66 million hectares.

Conclusions

In many parts of the Australia and around the world there is a big move to regenerative agriculture with the realisation that soil fertility has to be improved.

Dr Jones believes "The potential for reversing the net movement of CO_2 to the atmosphere through improved plant and soil management is immense. Indeed, managing vegetative cover in ways that enhance the capacity of soil to sequester and store large volumes of atmospheric carbon in a stable form offers a practical and almost immediate solution to some of the most challenging issues currently facing humankind. The key to successful sequestration is to get the basics right." [8]

Although in regenerative agriculture four ecosystem processes are proposed, any one of the four could be the starting point to drive the other three. Complex adaptive systems will reorganise themselves back to stability and health with minimum intervention once the four ecosystem processes are in place. Dr William Albrecht, the Father of modern soil sciences made the profound statement "The soil is the point at which the assembly line of life takes off". [1]

What better way to reduce the planet's greenhouse gases and a drying climate than to embrace regenerative agriculture. Healthy soils leads to healthy plants, healthy animal and healthy humans. A bonus is that biodiversity also improves. In Australia and across the world there are farming families transforming their land; one in particular can now enjoy the call of the Reed Warbler in their creek, a bird not heard for 130 years in their Australian landscape. [1]

Imagine if we could return our landscapes to something resembling the pre 1800s landscapes! It would take multiple generations, so there is no time to waste. However, we can all take a part in regenerating woodlands. There are planting days/festivals throughout Adelaide and the regions during winter and spring. BioR's projects Frahn's Farm near Monarto, Glenthorne Farm and Cygnet Park on Kangaroo Island, all need volunteers. The Friends of Parks website provides further opportunities. Bushfires have led to a big demand for seedling propagation so opportunities exist to volunteer as a grower for 'Trees for Life'. It will take generations to get the big trees back into woodland habitat, but regrowth of biodiverse habitats doesn't take many years. After four years, revegetated habitat on Cygnet Park was a sight to behold. (Back cover)

"Australia will need systematic incentives for reducing emissions in agriculture and land, and provide sound reasons that they are here to stay". [2] Recently, the Prime Minister announced that the Australian Renewable Energy Agency and the Clean Energy Finance Corporation will receive $1.4 billion over the next ten years and will be allowed to invest in new technologies, including soil carbon sequestration, which the Government says has the potential to lower Australia's emissions by 17%. Let us hope this further boosts the regenerative agricultural movement in Australia. Globally there is already a strong movement.

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Acknowledgement

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DUNG BEETLES - SAVIOURS OF THE AUSTRALIAN COUNTRYSIDE?

Dr Richard Willing

From the Archives: SEGments Volume 17, No. 2, 2001

It is time to turn our minds to dung - mountains of it - and a small worker that may save a drastic situation.

Cattle have been getting bad press lately, what with mad cow disease, foot and mouth disease, methane production to muck up the atmosphere and cholesterol to muck up our arteries. One unmistakable aspect requiring attention is that cows also produce large amounts of dung.

When you see cows grazing in the paddock consider that they are converting grass into meat, milk and dung. Each cow drops about 18 kg of dung per day. That means that a herd of 250 cows will produce more than 1600 tonnes of dung per year. Since European introduction 200 years ago the Australian cattle population has grown to 28 million - producing more than 180 million tonnes of dung per annum!

What happens to this dung mountain? Untreated it lies around the paddock producing patches of rank and unpalatable grass that is ignored by grazing animals - you have probably seen these clumps scattered through lightly grazed paddocks. In summer millions of flies are attracted and breed in the dung. In winter heavy rainfall may wash it into water-courses, introducing nutrients and increasing bacterial counts downstream - of great significance in water catchment areas for urban consumption.

Enter the dung beetles. These small fellows belong to a large world-wide family, some of which, endemic to Australia, have been cleaning up after our native fauna for ever. Some species have been introduced, and some have a taste for cow dung. These chaps fly in to a freshly dropped cow pat, burrow into it, consume nutrients, burrow into the soil beneath the pat and dig breeding chambers up to 30 cm below the surface. Into these they roll balls of dung and lay eggs. It is remarkable to see a cow pat disappear in a very short time after a swarm of dung beetles descend upon it. On lifting the remains the burrows can be seen going down into the earth.

The advantages of this system are obvious. Not only do they remove excess dung from the surface, but the dung beetles carry nutrients into the soil to enrich and aerate it. There is a marked diminution in fly population where they are active and run-off into waterways is diminished with improvement in water quality. Most South Australian dung beetles are active in summer. While this is a great bonus it is particularly important to have winter-active species in pastures when run-off is maximal. The Fleurieu Beef Group are helping to initiate the introduction of winter-active beetles to selected areas of the Fleurieu Peninsula, a trial which will be monitored for at least ten years.

So you can see the importance of this little chap in the maintenance of the health of our Australian environment (and water catchment.) Interested in a Dung Beetle Party for the next election? No bull-shit!

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DUNG BURIAL BY BEETLES AND ITS EFFECT ON SOIL ORGANIC CARBON

Dr Bernard Doube, Dr Agasthya Thotagamuwa and Loene Doube

Introduction

This document is an adaptation of a section in a manual being produced by the Food and Agricultural Organisation on the best soil management practices for soil organic carbon maintenance and sequestration. Bernard and Aga were invited to write a section on the capacity of dung burial by beetles to increase levels of soil organic carbon globally. The manual is expected to be published in December 2020.

An assessment of the opportunity to increase global stores of soil carbon by introducing new dung beetle species must consider the following: 1) the global distribution of dung beetle species (native and introduced); 2) the global production of dung; 3) the current capacity of established beetle communities to bury dung; 4) the contribution of buried dung to increase soil carbon stores in the short, medium and long term; 5) global gaps in the activity of dung beetles; 6) the availability of beetle species to fill gaps.

Global dung beetle communities

Globally there are over 7000 dung beetle species. Distinct and contrasting dung beetle communities are found associated with tropical, subtropical and temperate climates on all continents (except Antarctica), with distinct but partially overlapping communities in forest, woodland and grassland. In addition, season, soil type and the nature and abundance of the dung producers all influence the composition and functioning of dung beetle communities.

Dung beetles *Bubas bison* at work burying dung

Season

In even-rainfall, tropical and subtropical pastures dung beetle activity is linked largely to rainfall patterns, with most activity occurring during warm wet seasons. In tropical and subtropical regions dung removal during the dry season is commonly carried out by termites, although winter-active dung beetles also play a role in some habitats. In cool temperate regions dung beetle activity (mainly beetles that stay inside the dung pad and bury little dung) is confined to the warmer seasons of the year, while in some Mediterranean regions there is beetle activity in both the cool wet season and the hot dry season.

Vegetation and soil type

The diversity and abundance of dung beetle communities varies strongly with vegetation cover and soil type. However, species diversity also varies widely between land masses, especially in pasture, with some regions having few species while others are species rich. For example, some locations have few native grassland species (e.g. Britain, Canada), while in others (e.g. South Africa, West Africa) grassland species dominate the dung beetle fauna with high levels of species diversity and abundance. Soil type is a major determinant of the local distribution of dung beetles, with some species showing high specificity for one or another soil type while others have more cosmopolitan tastes.

Bubas bison dung beetles

Dung beetles and soil carbon

Dung beetles can be allocated to one of seven functional groups based on the nature of the way they deal with dung. Members of five of these groups **bury dung,** but the depth and location of the dung varies. Tunnellers (paracoprids), depending upon species and soil condition, place dung 1–200 cm beneath the dung pad or in the soil surrounding it, while ball rollers (telecoprids) bury dung balls at some distance (up to many metres) from the dung pad and at depths of 0–30 cm. Tunnellers and ball rollers occupy many different environments and are most abundant and effective in temperate, subtropical and tropical regions. The dung of most mammals and many birds can be buried by paracoprid and telecoprid beetles. A substantial proportion of the global dung beetle fauna is found in association with the dung of mammals and birds other than domestic stock and their dung type preferences can be relatively specific or wide ranging. Their preferences cover the spectrum from herbivore dung (with some overlap with other forms of decomposing organic matter such as mushrooms) through omnivore dung to carnivore dung (with some overlap with carrion beetles).

However, global forests and woodlands are shrinking rapidly along with the biodiversity and abundance of their associated indigenous dung producers and the beetles that deal with their dung. With global adoption of domestic stock as a primary food source (often on cleared forest or shrub lands), and the numbers and biomass of wildlife around the world being small compared with those of domestic stock, dung burial by beetles and the corresponding increase in soil organic carbon are largely restricted to pastures and rangelands grazed by domestic stock. Here we focus on the dung beetle fauna of the grasslands of the world, where there is high diversity of species in some locations and a paucity of species in others. Currently there are an estimated 1.0 billion cattle, 1.0 billion sheep, 800 million goats and 59 million horses globally.

Domestic livestock produce large amounts of dung which often sits unburied on the soil and eventually decomposes, releasing carbon dioxide to the atmosphere, but adding little carbon to the soil. Dung burial by dung beetles can substantially improve the **soil carbon** balance by incorporating dung into the soil, thereby increasing soil carbon and promoting plant root growth, which in turn adds additional carbon to the soil.

Pasture in many world regions supports dung beetle communities with low species diversity and a minimal capacity to dispose of the dung of domestic stock. This has led to widespread deliberate introduction of over 100 species of beetles to countries around the world. Despite this, there appears to be ample opportunity for further redistribution of these and additional species.

Beetle communities and global patterns of dung production

The global wave of megaherbivore extinctions during the late Pleistocene and Holocene periods represents one of the major ecological upheavals of the recent past, and the cascading effects of these extinctions on dung beetle diversity are profound. Large herbivorous mammals inhabited all of the warmer continents and larger islands, and on each isolated land mass their large moist dung deposits are considered to have supported a distinct mega dung beetle fauna, as still occurs in the African Game Parks. When the megafauna extinctions took place in regions where there was no large domestic stock (e.g. Australia, New Zealand, South America), many beetle species reliant on moist herbivore dung became extinct. The consequences of these historical extinction processes can be seen in the low diversity and activity of cattle dung beetles in many regions around the world, with some notable exceptions in which the presence of domestic stock and megaherbivores overlapped in time.

The outstanding exceptions are Eurasia and Africa, where there are many endemic dung beetle species in most grasslands (often 50–100+ species per location). Eurasia is the ancestral home of most domestic herbivore species as well as the European bison and so, historically, the supply of large herbivore dung has not been interrupted there. Similarly, in Africa the movement of cattle across north Africa and into southern Africa overlapped in time with the extensive occupation of the continent with a wide array of herbivores, thereby ensuring a seamless transition from dung beetles' reliance on wildlife dung to their reliance on cattle dung over the past millennia. The grasslands of the United States, where bison and cattle coexisted following European colonisation, have intermediate levels of diversity.

In other regions, such as South America, Australia and New Zealand, the megafaunal extinctions occurred before the introduction of cattle and the surviving smaller vertebrate herbivores produced dung piles that were neither large nor moist (e.g. llama and alpaca dung in South America, marsupial dung in Australia), which explains the low levels of cattle dung-adapted species in their grasslands. But even within regions of high species diversity there are some local regions with low species diversity, such as the United Kingdom and Mediterranean regions of southern Africa.

Global patterns of dung burial

Numerous methods have been employed to estimate the amount of dung buried by dung beetles but the overall conclusions are similar in that, in the absence of serious dung removal activity, dung decomposition on the soil surface commonly takes months or years. Dung removal by ball rollers is often complete within a few hours of the beetles' arrival at a dung pad, although some species may remain feeding in the pad for a day. Some tunnellers have secured their dung supply within a day or less of arrival at a pad, while other tunnellers, if present in low numbers, may continue burying dung from one deposit for days (even weeks) until the moist dung supply is exhausted. In contrast, at times of high abundance (hundreds or even thousands per pad) there is much dung shredding, during which dung fluids are removed, leaving dispersed, dryish dung fragments. This has led to the impact of dung beetles on dung pads being categorised into buried dung and shredded remains.

Up to a point, dung burial increases with increasing numbers of dung beetles per pad and moderate numbers of beetles can achieve complete dung burial (apart from the dry surface crust). This is true at low abundance but not always at high abundance, where mutual interference can reduce dung burial (and breeding) and increase shredding.

One excellent field study carried out on the southern African **highveld** assessed the seasonal changes in levels of dung removal in three habitat types (grassland, open woodland and thicket) on both clay and sandy soil in the wet and dry seasons. It found that after seven days a much higher proportion of dung was removed in the wet than in the dry season on both soil types, but that a higher proportion was removed on the sandy soil than on the clay soil. Another study showed that during the wet season in the South African **lowveld**, there was 80% burial within two days on a sandy soil, while on the nearby clay-loam soil dung burial after four days reached only 20%. In a long-term study in subtropical Australia the greatest dung burial by seven species of introduced dung beetles also occurred during the wet season, but overall the proportion of available dung buried was low, due to mutual interference between the many hundreds of medium-sized introduced beetles in each dung pad.

There are reports that when the Australian native *Onthophagus ferox* was the lone species present in parts of Mediterranean Western Australia, at the seasonal peak of abundance only 20% of the cattle dung was buried, and some years later, when the introduced *Onthophagus binodis* had become abundant, 45% was buried. Other estimates of dung burial by summer-active species reveal that *Onthophagus taurus* at low levels of abundance can largely bury dung pads over two weeks.

The relatively large winter-active **deep-tunnelling** beetle *Bubas bison* provides a stark contrast with these findings. *B. bison* has now been well-established in numerous regions in southern Australia for decades, and up to 400+ beetles per pad are common in the early part of the season. At these times, all dung pads are completely buried within 1–2 days of deposition and there is little or no shredding and no dry crust. Later in the season pads are still buried within a week and in regions where numbers are low one pair can completely bury a pad over several weeks, leaving only a dry crust. *B. bison* also completely buries the moist dung masses that sheep produce when on green pasture.

Global gaps in dung beetle communities

Indigenous grassland dung beetle communities that are species-poor are found in many regions of the world including Mexico, the Great Plains of North America, Western Australia, New Zealand, Mediterranean South Africa, Neotropical South America and Colombia. These gaps in dung beetle activity are reflected in low levels of dung burial and so these locations could benefit substantially from the introduction of cattle-dung-adapted species, of which there are many.

Impact of dung burial on carbon sequestration

The fresh dung of herbivorous mammals is commonly 40–85% water by weight and comprises a microbial soup mixed with partially digested plant fibre, commonly containing about 50% carbon. Twelve months after its burial, only 15+% of the carbon in buried dung remains in the soil. The remainder is metabolised by microbes and lost to the atmosphere through 'soil respiration', and released as plant nutrients to the soil, which increases pasture production and provides a corresponding increase in the deposition of root carbon.

When fresh cattle dung is deposited on a permeable soil, moisture containing some microbes (and the carbon they contain) and dissolved organic carbon (DOC) leaches into the shallow soil beneath the dung pad, but this comprises only a tiny proportion of the carbon present in the dung.

The burial of dung by beetles adds labile organic carbon (readily decomposed by soil microbes) to the soil and regular burial of such organic matter may well generate a new dynamic equilibrium in the turnover of soil organic matter, with elevated levels of soil carbon. Only small amounts of recalcitrant carbon (resistant to decomposition) remain in the soil to slowly build the permanent soil carbon pool. Two studies, carried out in southern Australia, show that dung burial by deep-tunnelling dung beetles can induce a substantial increase in the amounts of carbon present deep in the soil and that this can persist undiminished for two years.

In study 1, beetles were allowed to bury dung in soil cores in the field and the carbon present in different soil fractions (Table 1) was used to generate a carbon budget. These data show that 50% burial of a 5 kg dung pad (containing 400 g carbon) resulted in an increase of 70 g of carbon in the soil profile after 10 months, which equates to 30 g of carbon per kg of buried dung. This was considered to be due to the addition of dung carbon to the soil and the prolific growth of plant roots into the dung-enriched subsoil. The organic matter in plant roots contains about 50% carbon, on a dry weight basis.

In study 2, the persistence of elevated levels of dung-associated soil carbon was assessed on four occasions over two years in the field at two locations in South Australia (Kuitpo and Ashbourne). Dung burial increased the levels of organic carbon in the subsoil (20–50 cm) by 25% at Kuitpo and 70% at Ashbourne. There was no significant decrease over

An extracted dung + beetles soil core showing vigorous growth of vine roots entering the core after 10 months

Table 1: The organic carbon content (g) of the component parts of the soil cores in study 1

	Dung+beetles	Dung-only	Controls
Surface litter	43.6±18.6	50.6±6.3	3.0±1.1
Upper section	111.4±26.2	91.6±20.3	75.6±12.4
Basal section	78.2±34.0	58.4±25.0	74.2±15.3
Tunnels + contents	37.7±13.0		
Total per core	270.8±21.6	200.6±25.3	152.9±19.9

Soil from the same dung + beetles soil core (shown in previous photograph) showing the soil at the base. Vine roots, buried dung and larval capsules can be easily seen.

A control soil core (no dung or beetles) showing no roots in the soil. The total carbon in the control cores was 153 g per core, which was lower than the carbon in the dung-only or the dung + beetles cores.

time in levels of organic carbon in the subsoil in either soil type, a very encouraging result.

Potential for additional carbon storage in soil

Here, initially, we limit our considerations to the level of carbon storage in southern Australian soils that might arise from dung burial by two *Bubas* species (*B. bison* and the spring-active *B. bubalus*). If these beetles were widespread across southern Australia and buried 50% of the dung produced by the five million cattle in the region (of an national herd of 26 million), each producing 20 kg of fresh dung per day over 200 days, then a total of approximately 10 million tonnes of fresh dung would be buried annually. If the affected soil retained an extra 30 g of carbon per kg of fresh dung buried, the soil carbon store could be increased by 300 thousand tonnes of carbon or 1.1 m tonnes of CO_2 equivalent (CO_{2e}) annually. Annual additions for two years would lock up 2.2 million tonnes of CO_{2e}, approximately equivalent to 2% the total annual greenhouse gas emissions from agriculture in Australia. If globally 10% of one billion cattle could be subjected to this dung burial regime, then a total of 33 million tonnes of CO_{2e} (3% of global annual CO_{2e} production) could be sequestered every two years.

Additional benefits of dung burial

The improvements in soil properties brought about by dung burial by beetles are numerous. Dung burial generates tunnels into the soil (1–200 cm deep) and deposits substantial amounts of organic matter through the soil profile, dramatically improving the physical, chemical and biological properties of soil. The physical benefits include improved soil aeration, reduced bulk density and improved water infiltration. The chemical benefits include increased cation exchange capacity (influences the soil's ability to hold onto essential nutrients and provides a buffer against soil acidification), improved soil pH and increased plant nutrients and carbon throughout the soil profile. The biological benefits include increased microbial activity, increased plant root growth and more earthworms.

Other benefits include the biological control of dung-borne gut worms and dung-breeding flies. For example, large numbers of summer-active beetles (often thousands per dung pad) across wetter regions of southern Australia commonly destroy the breeding grounds of the pestilent bush fly and so, in these regions, the ‘Australian salute’ is a thing of the past, at least during summer. However, bush flies are still a problem during spring in some localities and during the summer in the arid zone (e.g. Central Australia), and so are a major pest of the Centralian cattle and tourist industries. Further, the bush fly is a vector for ‘pink eye’ in cattle and trachoma in people. We need biological control agents for cattle dung in spring and the arid zone.

In summary, it is clear that there are many regions around the world that lack a full complement of dung beetles year-round, on all soil types and in all habitats. Introductions in these regions could dramatically increase the amount of carbon sequestered in the soil, along with a string of other benefits. Such introductions are likely to have the greatest benefit in warm temperate regions that lack winter- and spring-active deep-tunnelling beetles. These areas include southern Australia, Mediterranean North and South America, and southern South Africa.

Dr Bernard Doube

Dr Bernard Doube OAM worked with CSIRO for 29 years, including 7 years as OIC of the CSIRO Dung Beetle Research Unit in Pretoria, South Africa. Since 2003 he has been the lead researcher and director of Dung Beetle Solutions International (DBSI), where he is strongly involved in research and farmer education. Bernard works in association with many research partners including water authorities, federal agencies (e.g. Meat and Livestock Australia), universities, and Landcare and other landholder groups. He has published many research papers on dung beetles, earthworms and the biological basis of soil health. Bernard is an adjunct researcher at Charles Sturt University and a theme leader in the Dung Beetle Ecosystem Engineers project. A major part of this work is the development and management of on-farm producer-managed field nurseries for mass rearing new species for wide distribution.

For more information on Dr Doube and DBSI go to Dung Beetle Solutions International.

Dr Agasthya Thotagamuwa

Dr Agasthya Thotagamuwa received his PhD in environmental entomology from the University of Colombo, Sri Lanka. His doctoral research focused mainly on the ecology and bioindicator potential of tiger beetles (Coleoptera: Cicindelidae) in Sri Lanka. Currently, Agasthya is working as a Technical Officer for the Dung Beetle Ecosystem Engineers Project at Charles Sturt University. He combines his experience in mass-rearing insects and reviewing scientific literature, and regularly consults beetle-rearing experts to understand the best conditions for mass rearing of dung beetles in both controlled-climate and outdoor rearing facilities.

Loene Doube

Loene Doube is an accredited professional editor and has had a career as an IT and publications manager. Until her retirement in 2014 she was an educational designer at Flinders University, and then joined her partner, Bernard Doube, at Dung Beetle Solutions International, where her roles include managing the business, editing and providing technical assistance. Loene serves on the steering committee for the Charles Sturt Dung Beetle Ecosystems Engineering project, and contributes to the contracted work of Dung Beetle Solutions International.

All photographs Bernard Doube

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NOTICE OF ANNUAL GENERAL MEETING

The 36th Annual General Meeting will be held on **FRIDAY 30th October 2020 @ 7.30 pm**

FULLARTON PARK COMMUNITY CENTRE - PARKVIEW ROOM

411 Fullarton Road, Fullarton SA 5063

After a short business meeting our guest speaker Dr. Tony Robinson will talk on

"The Kangaroo Island Fires – One Year On"

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INTERIM REPORT OF THE INDEPENDENT REVIEW OF THE ENVIRONMENT PROTECTION AND BIODIVERSITY CONSERVATION ACT 1999 (EPBC ACT)

Dr Robert Sharrad AM

Professor Graeme Samuel AC has recently introduced this interim report. He and his panel of experts have been working on the review since October 2019 and aim to produce a final report by October 2020. The interim report can be seen on the website: (https://epbcactreview.environment.gov.au/resources/interim-report) What, you may ask, is the EPBC Act? Again one can look to the appropriate website for a definition – see below:

"The *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act) is the Australian Government's central piece of environmental legislation. It provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places — defined in the EPBC Act as matters of national environmental significance." (https://www.environment.gov.au/epbc)

You can see that the EPBC Act should be a most important protection for the things that we in SEG hold dear. However the review panel are damning in their criticism of the effectiveness of the Act. The interim report points out that environmental and cultural features of the Australian landscape continue to be degraded and that there need to be very large changes to reverse the trend. You will be able to think of many examples of this degradation, here are two such cases: the continuing clearing of woodland in Qld (the WWF reckons we are in the top 11 countries in the world for deforestation); and, the recent destruction in WA of rock shelters which showed ancient occupation by ancestors of our Indigenous Australians.

Of course you will know that the states and territories play a major part in these matters and they have their own Acts which apply. Prof Samuel's team see that: "The construct of Australia's federation means that the management of the environment is a shared responsibility and jurisdictions need to work effectively together, and in partnership with the community." This working together will continue to be a great challenge – as we have seen recently in the current pandemic. The panel also notes that at times there is duplication between the Commonwealth and State and Territory regulatory frameworks – another source of inefficiency.

Indigenous Australians are particularly mentioned in the interim report. The panel underlines the fact that the EPBC Act fails Indigenous Australians and points out that their views and knowledge are not adequately taken into account in decision making.

The panel also believes that the information on which decisions are made is not always the best available and they note that "there is no single national source of truth that people can rely on". They allocate quite a proportion of the report to this subject. Interesting isn't it at this time with environmental degradation so obvious (think of the recent fires) and the need for sound information so important (as the interim report details) that the professional staffing levels of the South Australian Museum and State Herbarium are at such appallingly low levels! I won't spell out all the matters raised by Prof Samuel's team, the failings of the current Act and the changes needed, but recommend you look at the summary at least of the interim report.

Since the Federal Government has now made changes to the Act (passed in September by the House of Representatives), conservationists are lobbying cross-bench Senators to oppose the changes, which hand over environmental approval powers to states and territories. We see that there are some who want to weaken rather than strengthen regulations, since ecosystems, rivers, forests and wildlife cross state borders! We need to be vigilant.

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Editorial continued from Page 1

If Craig Reucassel's revelations can encourage Australians to take positive steps to reduce or offset their carbon footprints, then perhaps Australia's greenhouse gas emissions can be reduced with less demand for new renewable energy sources: **energy which is far from environmentally cost-free** and comes ultimately from the earth.

Ref: "Super-Power. Australia's low-carbon opportunity", Ross Garnaut, 2019

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MINNAWARRA BIODIVERSITY SURVEY SPRING 2020

Unfortunately the Spring Survey has had to be a private survey. We hope to open the Autumn Survey to interested parties.

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