Soil carbon - can it save agriculture's bacon?

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The number of farmers in Australia has fallen 30 per cent in the last 20 years, with more than 10,000 farming families leaving the agricultural sector in the last five years alone. This decline is ongoing. There is also a reluctance on the part of young people to return to the land, indicative of the poor image and low income-earning potential of current farming practices.

Agricultural debt in Australia has increased from just over $10 billion in 1994 to close to $60 billion in 2009 (Fig.1). The increased debt is not linked to interest rates, which have generally declined over the same period (Burgess 2010).

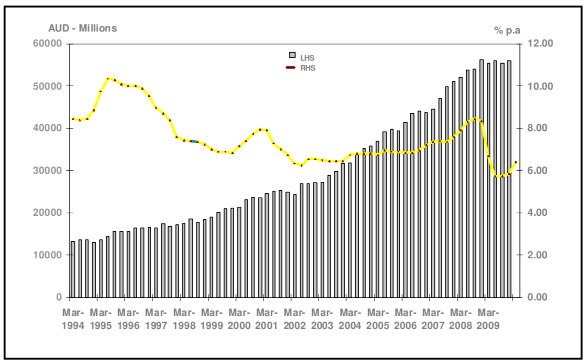

Fig. 1. Increase in agricultural debt (AUD millions) 1994-2009 vs interest rates (%pa)

The financial viability of the agricultural sector, as well as the health and social wellbeing of individuals, families and businesses in both rural and urban communities, is inexorably linked to the functioning of the land.

There is widespread agreement that the integrity and function of soils, vegetation and waterways in many parts of the Australian landscape have become seriously impaired, resulting in reduced resilience in the face of increasingly challenging climate variability.

Agriculture is the sector most strongly impacted by these changes. It is also the sector with the greatest potential for fundamental redesign.

The most meaningful indicator for the health of the land, and the long-term wealth of a nation, is whether soil is being formed or lost. If soil is being lost, so too is the economic and ecological foundation on which production and conservation are based.

The soil carbon sink

In July 2009, the Portuguese government introduced an AUD$13.8 million soil carbon offsets scheme based on dryland pasture improvement, compliant with Article 3.4 of the Kyoto Protocol. The scheme will pay an estimated 400 participating farmers to establish biodiverse perennial mixed grass/legume pastures (upwards of 20 species) to improve soil carbon, soil water holding capacity and livestock productivity in an area of approximately 42,000 hectares (Watson, 2010).

The Portuguese scheme has been designed to comply with Kyoto's strict criteria of additionality and permanence. Coordinator of Project Extensity and Terraprima project leader, Professor Tiago Domingos, has calculated that the area of agricultural land in Portugal amenable to soil carbon offsets could collectively sequester more than the current Portuguese national emissions deficit under existing Kyoto arrangements (Watson 2010).

The mediterranean-type climate of central and southern Portugal is very similar to that in many parts of south-eastern, southern and south-western Australia. The Portuguese Terraprima data illustrated in Fig.2 show that under sown perennial pasture, soil organic matter increased to a level of 3% over 10 years, from a starting point of 0.87%.

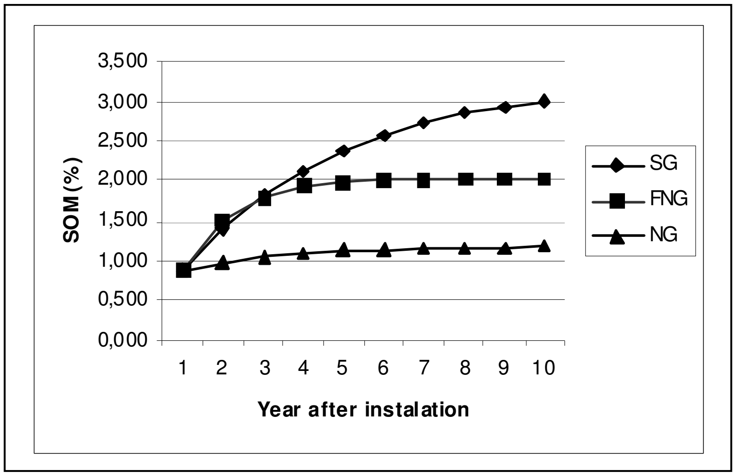

Fig. 2. Accumulation of soil organic matter (SOM), shown as percentage by weight, in soils under three pasture types.

SG = sown perennial pasture; FNG = fertilised annual pasture; NG = unfertilised annual pasture (from Watson 2010).

The Portuguese soil carbon offsets project aims to sequester 0.91 million tonnes of CO_2 from 2010 to 2012 (Watson 2010). This equates to the sequestration of 10.85tCO_2/ha/yr.

In addition to the carbon payments they receive, participating Portuguese farmers are reported as “enjoying the environmental spin-offs of greater biodiversity, higher soil fertility, higher water infiltration rates, less erosion, less desertification, fewer fires, less floods, improvement in water quality, less dependence on concentrated feed for their herds in protracted dry periods and better milk and meat quality” (Watson 2010).

US study on soil carbon sequestration rates under perennial grassland

Recent research by United States Department of Agriculture (Liebig *et al.* 2008) investigated soil carbon sequestration under a perennial native grass, switchgrass (*Panicum virgatum*) grown for the production of cellulosic ethanol.

Despite the annual removal of aboveground biomass, low to medium rainfall and relatively short growing season, the USDA-ARS research, averaged across 10 sites recorded average soil carbon sequestration rates of 4tCO_2/ha/yr in the 0-30 cm soil profile and 10.6tCO_2/ha/yr in the 0-120 cm profile (Liebig et al 2008)

The best performing site was at Bristol, where soil carbon levels increased by 21.67 tonnes in the 0-30 cm soil profile over a 5 year period. A soil carbon increase of 21.67tC/ha equates to the sequestration of 80tCO_2/ha.

At the three sites where carbon was measured to 120 cm, the USDA research found relatively high sequestration rates below 30 cm. The sequestration rate was higher for the 30-60 cm increment than for the 0-30 cm increment (18.2tCO_2/ha vs 16.5tCO_2/ha, respectively). A possible interpretation is that the deeper the sequestration, the greater the likelihood that the carbon be protected from oxidative and/or microbial decomposition.

There were virtually no ‘biomass inputs’ to soil in these trials, as all aboveground material was removed for ethanol production. This suggests the liquid carbon pathway (Jones 2008) as the primary mechanism for soil building.

Carbon trading in the real world

The recent demise of the Federal Government’s proposed Carbon Pollution Reduction Scheme provides an opportunity to reflect on the true meaning of a carbon-based economy.

For some time, analysts have tipped carbon to become the world’s most traded commodity. The reality is that it has been the world’s most traded commodity for millennia.

A great variety of life forms require liquid carbon - referred to in the scientific literature as ‘dissolved organic carbon’ (DOC) - for their growth and reproduction. The growth of trees, crops and pastures, for example, requires the transport of dissolved carbon via sap within the plant; animal growth is dependant on the digestion of carbon containing foods and the transport of dissolved carbon to cells via the blood; the formation of topsoil is dependent on photosynthesis and the transport of dissolved carbon, via a microbial bridge, from plants to soil.

Carbon is the currency for most transactions within and between living things. Nowhere is this more evident than in the soil. Here, carbon is king. Mycorrhizal fungi, which are totally dependant on dissolved organic carbon from green plants, trade carbon with colonies of bacteria located at their hyphal tips in exchange for macro-nutrients such as phosphorus, organic nitrogen and calcium, trace elements such as zinc, boron and copper, and plant growth stimulating substances (Killham 1994, Leake *et al.* 2004).

By means of an extraordinary physiological process known as ‘bidirectional flow’ nutrients are transported to roots at the same time as dissolved organic carbon moves through fungal hyphae in the opposite direction (Killham 1994, Leake *et al.* 2004). Indeed, mycorrhizal roots are significant sinks for carbon, transferring as much as 15 times more carbon to soil as adjacent non-mycorrhizal roots (Killham 1994).

Impoverishment of agricultural soils

Mycorrhizal fungi and associative bacteria are very strongly inhibited by excessive soil disturbance and the high levels of water-soluble phosphorus and nitrogen commonly used in modern agriculture (Killham 1994, Leake *et al.* 2004). Where soils have been subjected to cultivation and/or the application of MAP, DAP, superphosphate, urea or anhydrous ammonia, the suppressed mycorrhizal colonisation of plant roots significantly reduces carbon flow. The structural degradation of agricultural soils, accompanied by mineral depletion in food, has largely been the result of the inhibition of this natural carbon pathway.

When carbon supply is limited by the loss of the primary pathway for sequestration, the physical, chemical and biological functions normally performed by healthy soil are markedly reduced.

Historical levels of soil carbon

Noted Polish explorer and geologist, Sir Paul Edmund [Count] Strzelecki, travelled widely through the colonies of south-eastern Australia during the period 1839 to 1843, collecting minerals, visiting farms and analysing soils. One of the questions Strzelecki posed was, what factors determine soil productivity? He collected 41 soil samples from farmed paddocks of either high or low productivity. The analyses revealed that the most important determinant of soil productivity was the level of soil carbon (measured as organic matter in Strzelecki’s day).

Of the 41 samples analysed, Strzelecki (1845) found …

The top 10 soils in the high productivity group had organic matter levels ranging from 11% to 37.75% (average 20%). The lowest ranking 10 soils in the low productivity group had organic matter levels ranging from 2.2% to 5.0% (average 3.72%)

The soils with the highest organic matter levels also had the highest moisture holding capacity, with an 18-fold difference in capacity to hold moisture between the lowest and the highest (Strzelecki 1845).

Strzelecki's data indicate that organic matter levels in the early settlement period were around five to ten times higher than in many soils today. The soil test data from Strzelecki is consistent with the writings of first settlers, who described soils in the early settlement period as soft, spongy and absorbent. The 1840s journal of George Augustus Robinson, for example, contains numerous references to the extremely fertile and productive soils encountered by pastoralists in the mid-1800s (Presland 1970).

Soil carbon and soil moisture

In addition to enhancing nutrient availability, carbon performs many other functions in soil, including the maintenance of soil porosity, aeration and water-holding capacity.

Glenn Morris (Morris 2004) extensively researched the water holding capacity of humus (an extremely stable form of soil carbon) and concluded that within the soil matrix, one part of soil humus could, on average, retain a minimum of four parts of soil water.

From this relationship it can be calculated that an increase of 16.8 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 1.4 g/cm^3, for every 1% increase (in absolute terms) in the level of soil organic carbon. This equates to 168,000 litres of water that could be stored per hectare, in **addition** to the water-holding capacity of the soil itself (Jones 2006).

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

Soil organic carbon levels in many areas have fallen by at least 3% (in absolute terms) since the time of European settlement, **This reduction in soil carbon content represents the LOSS of the ability of soil to store around 504,000 litres of water per hectare.**

Mycorrhizas and water

It is well known that mycorrhizal fungi access and transport nutrients in exchange for carbon from the host plant (Killham 1994, Leake *et al.* 2004). What is less well known is that in seasonally dry, variable, or unpredictable environments (that is, most of Australia), mycorrhizal fungi play an extremely important role in plant-water dynamics.

Mycorrhizal fungi can supply moisture to plants in dry environments by exploring micropores not accessible to plant roots. They can also improve hydraulic conductivity by bridging macropores in dry soils of low water-holding capacity (such as sands). In these situations, external wicking along the hyphae is of greater importance than cytoplasmic flow (Allen 2007). Mycorrhizal fungi can also increase drought resistance by stimulating an increase in the number and depth of plant roots.

Soil carbon and soil nitrogen

Aside from water, nitrogen is frequently the most limiting factor to crop and pasture production. It is one of the great ironies of agriculture that the atmosphere is around 78% nitrogen, but not one single molecule is directly available to plants. There are approximately 78,000 tonnes of nitrogen gas sitting above every hectare of land. Apart from small accessions via lightning, this nitrogen cannot be accessed without a microbial bridge.

Nitrogen-fixing bacteria - be they free-living in the rhizosphere, confined to nodules on plant roots, or existing as endophytes in leaves or stems - derive most of their energy from liquid carbon fixed during photosynthesis.

Adding water-soluble nitrogen in the form of urea, anhydrous ammonia or nitrate destabilises the plant-soil ecosystem by reducing the activity of mycorrhizal fungi and free living N-fixing bacteria (Killham 1994). The presence of high levels of water-soluble nitrogen in soil sends a signal to plants to reduce the supply of liquid carbon to microbial symbionts, effectively inhibiting the microbial associations that would otherwise supply atmospheric nitrogen for free.

This contradicts the widely promoted belief that nitrogenous fertiliser needs to be added in order for stable soil carbon to form. Indeed, the opposite is true (Khan *et al.* 2007, Larson 2007, Mulvaney *et al.* 2009).

Soil test data show that as soil carbon levels increase in microbially active soils, availabilities of P, K, S, Ca, Zn and B commonly increase, while levels of nitrate nitrogen are often reduced.

If plants are mycorrhizal, they don't require nitrogen in a mineralised form, that is, in the form of nitrate or ammonium. In order to transport mineralised nitrogen, mycorrhizal fungi have to convert it to glutamate, which represents an energy cost. For this reason, nitrogen is preferentially transported in an organic form, generally as amino acids such as glycine and glutamine (Leake *et al.* 2004).

Utilisation of organic nitrogen by mycorrhizal fungi closes the nitrogen loop and prevents soil acidity, as well as preventing volatilisation of nitrogen to the atmosphere and leaching to aquifers, rivers and streams. Changes to soil chemistry and nitrogen dynamics in microbially balanced soils also reduce the abundance of ‘weedy’ species such as annual ryegrass, capeweed, mustard weed and thistles. The germination of these species is stimulated by the ready availability of nitrate nitrogen.

Soil as a methane sink

Wetlands, rivers, oceans, lakes, plants, decaying vegetation (especially in moist environments such as rainforests) - and a wide variety of creatures great and small - from termites to whales, have been producing methane for millions of years. The rumen, for example, evolved as an efficient way of digesting plant material around 90 million years ago.

Ruminants including buffalo, goats, wild sheep, camels, giraffes, reindeer, caribou, antelopes and bison existed in greater numbers prior to the Industrial Revolution than are present today. There would have been an overwhelming accumulation of methane in the atmosphere had not sources and sinks been able to cancel each other over past millennia.

Although most methane is inactivated by the hydroxyl (OH) free radical in the atmosphere (Quirk 2010), another source of inactivation is oxidisation in biologically active soils. Aerobic soils are net sinks for methane, due to the presence of methanotrophic bacteria, which utilise methane as their sole energy source (Dunfield 2007). Methanotrophs have the opposite function to methanogens, which bind free hydrogen atoms to carbon to reduce acidosis in the rumen.

Recent research undertaken by Professor Mark Adams, Dean of the Faculty of Agriculture at Sydney University, has found that biologically active soils can oxidise the methane emitted by cattle carried at low stocking rates (Cawood 2010). The highest methane oxidation rate recorded in soil to date has been 13.7mg/m^2/day (Dunfield 2007) which, over one hectare, equates to the absorption of the methane produced by approximately 100 head of cattle.

In Australia, it has been widely promoted that livestock are a significant contributor to atmospheric methane and that global methane levels are rising. However, there is no evidence to suggest that methane emissions from ruminant sources are increasing. Indeed, it would seem there has been **no clear trend to changes in global methane levels, from any source, over recent decades.**

The increase in global methane levels from 1930 to 1970 was due to emissions from the production, transmission and distribution of natural gas (Quirk 2010). There was a tenfold increase in the use of natural gas through the 1960s and 1970s. The source of many of the natural gas emissions, such as leakages from the Trans-Siberian pipeline, have since been rectified (Quirk 2010). Measurements over the last 25 years show concentrations of atmospheric methane are merely exhibiting natural variation, with no significant trends in any direction (Fig.3).

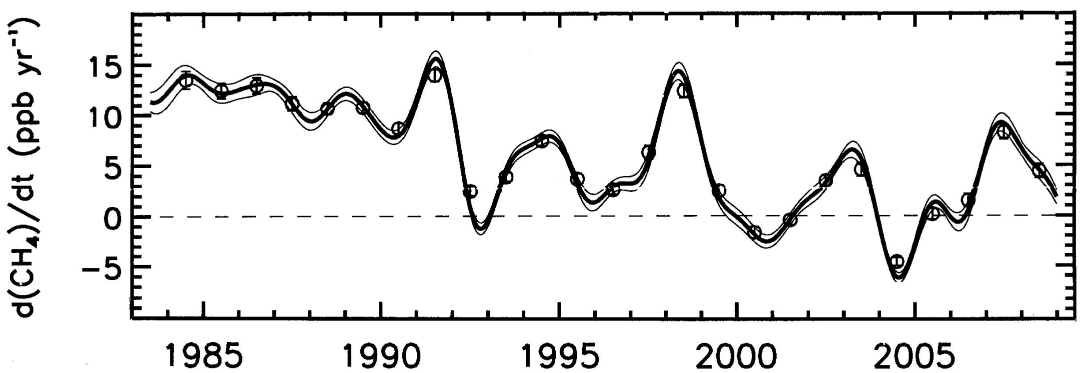

Fig. 3. Variations in annual changes in atmospheric methane concentrations from 1983 to 2009, from Dlugokencky *et al.* (2009). Measurements are in parts per billion per year.

There is therefore no scientific basis for selectively targeting ruminants for a 'methane tax', or worse, interfering with this natural process. Farming in ways that enhance, rather than inhibit, soil biological activity, would improve the capacity of agricultural soil to act as a methane sink, helping balance the greenhouse equation. The issue with today’s industrialised approach to agriculture is that methanotrophic bacteria are chemically sensitive. Their activities are reduced by nitrogenous fertilisers, herbicides, pesticides, acidification and excessive soil disturbance (Dunfield 2007).

Soil carbon and human health

The nutritional status of soils, plants, animals and people has fallen dramatically in the last 50 years, due to losses in soil carbon, the key driver for soil nutrient cycles. Soil health and human health are more deeply connected than many people realise. Food is often viewed in terms of quantity available, hence ‘food scarcity’ is not seen as an issue in Australia. However, food produced from depleted soils does not contain the essential trace minerals required for the effective functioning of our immune systems.

Routine premature deaths from degenerative conditions such as cardiovascular disease and cancer have become prominent when they were once relatively uncommon. The cancer rate, for example, has increased from approximately 1 in 100, fifty years ago, to almost 1 in 2 today. The effectiveness of the human immune system has been compromised by increased exposure to more and more chemicals coupled with insufficient mineral density in food.

The low nutritional status of many basic food items is highlighted in data from the UK Ministry of Health. Depletion in the level of minerals in vegetables for the period 1940-1991, for example, shows copper levels reduced by 76%, calcium by 46%, iron by 27%, magnesium by 24% and potassium by 16%. Deficiencies in plants translate through to deficiencies in animals. A piece of steak now contains only half the amount of iron that it would have contained 50 years ago.

Vitamin and mineral deficiencies in food indicate that the symbiotic relationship between plants and soil microbes, whereby minerals are exchanged for liquid carbon, has been disrupted.

The best national health policy would be a national soils policy. But we don’t have one.

Our hospitals are over-filled and our health system is struggling to cope with illnesses that are highly correlated to the lack of essential vitamins, minerals and trace elements in our diet. The availability of these nutrients is determined to a large extent by the integrity of the soil food-web and the microbe bridge, which in turn are dependent on active soil sequestration of dissolved organic carbon.

Food labelling and a ‘Soil Integrity Index’

Food choices can have very significant effects on the kind of food produced and how it is produced. Currently, it is not possible for consumers to choose foods high in minerals, grown on healthy soils, as there is no labelling for food quality.

It is proposed that a ‘Soil Integrity Index’ with index parameters of

i) level of microbial diversity
ii) soil carbon content and
iii) soil water holding capacity

be used as the basis for a food labelling system.

The labels would need to be simple, with perhaps a star system (as in one, two or three stars). If a food labelling mechanism was in place, Australia’s largely city-based population could use food choices to improve not only the health of their families, but also the function and resilience of agricultural soils, thereby actively participating and supporting biology friendly farming.

The future landscape

The challenge for the future prosperity of Australian agriculture is to convert soil from its current status as a net source of carbon, to a revitalised state as a net carbon sink.

Agricultural research tends to focus on conventionally managed crop and pasture lands where intensive use of agrochemicals has dramatically reduced the number and diversity of soil flora and fauna, including beneficial microbes such as mycorrhizal fungi. As a result, the potential contribution of microbial symbionts to agricultural productivity has been greatly underestimated (Allen 2007).

Building soil carbon does not require adding biomass to soil. While crop stubbles and mulch are important for protecting soil from wind and water erosion and buffering temperature extremes, their contribution to soil carbon is limited by eventual decomposition to CO_2.

The first step to restoring soil function is ‘do no harm’. A simple change from high-analysis N and/or P fertilisers to biological products such as worm leachate (vermiliquid), compost extract, seaweed extract and/or fish emulsion, applied as a seed dressing and/or a post-emergent foliar spray, will support microbial diversity, increase plant photosynthetic rate, increase the flow of liquid carbon to soil and enhance humification.

As the soil chemistry adjusts and nitrogen is converted to an organic form (freely available to mycorrhizal fungi but not to annual weeds) the incidence of pests, weeds and diseases that are stimulated by low levels of microbial diversity and high rates of water soluble nitrogen, will decline. As a result, there will be less reliance on the use of pesticides and herbicides that reduce the ability of soil to act as a sink for carbon, nitrogen, methane and moisture.

Changing the face of agriculture

Since 1960, global food production has doubled. At the same time, the soil resource on which food production is based has become seriously degraded.

The impoverishment of agricultural soils through depleted levels of biological activity and reduced carbon flow poses a greater threat to human existence than climate change.

In many regions of Australia, the effects of lower than average rainfall over the past decade have been compounded by loss of soil resilience and reduced moisture-holding capacity (Fig.4).

Fig. 4. Cropping over an old fence-line clearly demonstrates the extent to which soil has been depleted by conventional farming practices. Paddocks on either side of the fence have a history of high nitrogen application (Photo Richard May).

It has been calculated that in the next 50 years, the planet will need to produce as much food as it has in the entire history of humankind. The way we produce that food will require a radical departure from business as usual.

At the beginning of this paper it was noted that the level of agricultural debt in Australia had increased almost 6-fold over the last 15 years. The amount of money invested by the farming community on non-biological inputs increases every year. Many of these products inhibit microbial diversity, preventing natural carbon flow to soils. Cessation of carbon flow reduces soil integrity, the mineral density in food and human health. It also prevents the processes of humification and topsoil formation from operating to any significant extent. The end result is even greater expenditure on agrochemicals in attempts to control the pest, weed, disease and fertility ‘problems’ that ensue.

The statement that small farmers need to ‘get big or get out’ overlooks the fact that profit is the difference between expenditure and income. In years to come we will perhaps wonder why it took so long to realise the futility of trying to grow crops in dysfunctional soils, relying solely on increasingly expensive synthetic inputs.

Economic development is only sustainable if it strengthens, rather than depletes, natural resources.

The soil’s ability to produce nutrient dense, high vitality food - which after all, is agriculture’s real purpose - depends on appropriate management. Enhancing the natural flow of carbon to soils will result in increased microbial diversity, improved nutrient cycles, enhanced soil water-holding capacity, greater resilience, improved catchment health - and a more satisfying, profitable future for farmers.

The longer we delay undertaking regenerative changes to land management based on biology friendly farming practices that rebuild carbon-rich soils, the more soil carbon and soil water will be lost, exposing an increasingly fragile agricultural sector to escalating production risks, rising input costs and vulnerability to climatic extremes.

Its time to move away from depletion-style, high emission, chemically based industrial agriculture and get serious about grass-roots biologically based alternatives.

The future of Australia depends on the future of our soil - and our willingness to look after it.

Rebuilding soil productivity via the restoration of natural carbon flow and the sequestration of stable soil carbon is the only means of saving agriculture’s bacon - and ensuring a future for human society as we know it.

Literature cited

Allen, M.F (2007). ‘Mycorrhizal fungi: highways for water and nutrients in arid soils’. *Soil Science Society of America, Vadose Zone Journal.* Vol 6 (2) pp. 291-297. DOI:10.2136/vzj2006.0068.

Burgess, N. (2010). Agricultural debt from 1994 to 2009. *Sourced from Westpac Economics & Reserve Bank of Australia.* nburgess@westpac.com.au

Cawood, M. (2010). Error in Snowy soils carbon report.

http://theland.farmonline.com.au/news/state/agribusiness-and-general/general/error-in-snowy-soils-carbon-report/1887462.aspx

Dlugokencky, E. J. et al. (2009). Observational constraints on recent increases in the atmospheric CH4 burden. *Geophysical Research Letters*. 36, L18803, DOI:10.1029/2009GL039780.

Dunfield, P. F. (2007). The soil methane sink. In D.S. Reay, C.N. Hewitt, K.A Smith and J. Grace, eds. Greenhouse Gas Sinks. pp. 152-170. Wallingford UK.

Jones, C. E. (2006). Carbon and catchments. *National ‘Managing the Carbon Cycle’ Forum,* Queanbeyan, NSW, 22-23 November 2006. http://www.amazingcarbon.com

Jones, C.E. (2008). Liquid carbon pathway unrecognised. *Australian Farm Journal,* July 2008, pp. 15-17. http://www.amazingcarbon.com

Khan, S.A, Mulvaney, R.L, Ellsworth, T.R. and Boast, C.W. (2007). The myth of nitrogen fertilization for soil carbon sequestration. *Journal of Environmental Quality* 36:1821-1832. DOI:10.2134/jeq2007.0099

Killham, K. (1994). 'Soil Ecology'. Cambridge University Press.

Larson, D. L (2007). Study reveals that nitrogen fertilizers deplete soil organic carbon. *University of Illinois news*, October 29, 2007. http://www.aces.uiuc.edu/news/internal/preview.cfm?NID=4185

Leake, J.R., Johnson, D., Donnelly, D.P., Muckle, G.E., Boddy, L. and Read, D.J. (2004). Networks of power and influence: the role of mycorrhizal mycelium in controlling plant communities and agroecosystem functioning. *Canadian Journal of Botany*, 82: 1016-1045. DOI:10.1139/B04-060

Liebig, M.A, Schmer, M.R, Vogel, K.P. and Mitchell. R.B. (2008). Soil carbon storage by switchgrass grown for bioenergy. *Bioenergy Research* 1: 215-222. DOI:10.1007/s12155-008-9019-5

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.

Mulvaney, R.L, Khan S.A, and Ellsworth, T.R. (2009). Synthetic nitrogen fertilizers deplete soil nitrogen: a global dilemma for sustainable cereal production. *Journal of Environmental Quality* 38:2295-2314. DOI:10.2134/jeq2008.0527

Quirk T. W. (2010). Twentieth century sources of methane in the atmosphere. *Energy and Environment,* 21(3), pp. 251-256.

Strzelecki, Paul Edmund de, (1845). Physical description of New South Wales and Van Diemen's Land: accompanied by a geological map, sections and diagrams, and figures of the organic remains / by P.E. de Strzelecki. Printed for Longman, Brown, Green, and Longmans, London. (Note: prior to 1851 the state of Victoria was part of the colony of New South Wales).

Watson, L. (2010). Portugal gives green light to pasture carbon farming as a recognised offset. *Australian Farm Journal*, January 2010, pp. 44-47.