Submission to the Environment and Natural Resources Committee

Inquiry into Soil Sequestration in Victoria

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Sincerely

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Executive Summary

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.

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

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

Active and ongoing soil sequestration of atmospheric carbon dioxide and the rebuilding of carbon-rich topsoil is one of the greatest challenges - if not the greatest challenge - facing human societies around the world.

It is an achievable goal.

The Victorian Government could support the benefits of soil sequestration by underwriting a Soil Stewardship Scheme involving rural communities, educational and advisory networks, the voluntary carbon market and corporate business. The proposed stewardship scheme would provide financial incentive and community and technical support for farmers to engage in natural soil-building processes, restore ecological integrity to agricultural land and actively sequester industrial emissions of carbon dioxide. Demonstrated social, environmental and productivity benefits should ensure natural expansion beyond the initial stewardship phase. The estimated cost to the Victorian Government would be $7.4 million over 5 years.

Background

The driver for soil sequestration is the photosynthetic capacity of groundcover. Soil must be covered with living plants in order for the sequestration process to begin. Completion of the process, that is, the conversion of liquid photosynthate to stable soil carbon, requires the movement of dissolved organic carbon (DOC) from green leaves to the soil matrix via a functional microbe bridge and humification of this carbon within an active soil food-web.

The historical record reveals that at the time of European settlement, the vegetative cover of Victoria, particularly to the north and west of Port Phillip Bay, was predominantly summer-green perennial grasslands and grassy woodlands. Descriptions from the mid-1800s of luxuriant, verdant meadows, colourful wildflowers, magnificent soils and waterways teeming with fish and abundant bird life (Appendix A) makes one wonder whether the authors were talking about the same countryside we see today.

Landscape function, in particular the water and nutrient cycles, are highly dependant on the quality and perenniality of groundcover, which in turn determines soil building and soil carbon levels. At the time of settlement, Victoria soils were generally high in soil carbon. Noted explorer and geologist Sir Paul Edmund Strzelecki recorded levels of organic matter in farmed soils in the 1840s as high as 37.75% (Appendix B).

In little over 170 years the ecological integrity of soil and all that depends on it has markedly declined. Despite genuine efforts to implement 'best practice' in soil conservation, the situation continues to deteriorate.

"The nation that destroys its soil destroys itself" (Roosevelt 1937).

The soil sequestration of atmospheric carbon is an active biological process. The carbon cycle would not, and can not, exist without green plants and their associated microbes (Appendix D). The current lack of sequestration in Victorian soils reflects an underlying biological dysfunction, requiring a biological solution. There are no technological quick fixes.

Terms of reference

(a) explore possible benefits to the agricultural industry;

Improvements to the quality, quantity and perenniality of groundcover in broadacre cropping, horticultural, silva-pastoral and grazing enterprises result in enhanced rates of soil sequestration and soil structural integrity (Appendix D), higher levels of soil carbon (Appendix E) and a greater diversity of soil life (Appendices G and H), conferring multiple ecological and production benefits in terms of nutrient cycling (Appendix F), plant, animal and human nutrition (Appendix J), soil water storage (Appendix I), disease suppression, reduced salinisation and acidification (Appendix F) and above- and below-ground biodiversity (Appendix G).

Rebuilding carbon-rich agricultural soils via the adoption of a community based Soil Stewardship Scheme (Appendix K), focussed on the restoration of biodiverse summer-green perennial groundcover and biology-friendly forms of farming, would have multiple long-term benefits to agricultural industries, including

- formation of new topsoil
- rehydration of the landscape (improved water cycle)
- significant fire retardation benefits (summer-green perennial pastures are difficult to burn whereas summer-brown annual winter pastures are a fire hazard)
- drought-proofing of farms (diverse perennial pastures can respond to rain at any time of year)
- enhanced farm profitability (vertical stacking of enterprises such as cropping, grazing and seed production on the same area of land)
- value-adding to existing agricultural practices and products
- creation of new regional business opportunities
- improved social cohesion between farming families
- development of ancillary industries (seed production, biological fertilisers, biofuels)
- provision of a framework for soil carbon trading via project-based soil carbon offsets and participation in the voluntary carbon market
- increased soil microbial diversity and stability
- enhanced nutrient cycling
- improved plant and animal nutrition
- reduced need for supplementary feeding of livestock
- fewer plant and animal disease problems
- formation of mycorrhizal guilds (these do not form in annual-based farming systems)
- normalisation of soil pH and reduced levels of soil acidity
- greater soil aggregate stability
- improved soil structure

- enhanced infiltration of rainfall
- reduced erosion
- enhanced water-use efficiency
- higher soil cation exchange capacity
- decreased soil aluminium toxicity
- decreased soil sodium activity
- improved nitrogen cycle and reduced reliance on synthetic nitrogen inputs
- lower fuel and fertiliser costs
- improved food security
- higher mineral density in food
- improved resilience of agricultural production in a warming, drying climate
- revitalisation of rural communities
- development of a template for community involvement in landscape restoration that could be applied Australia-wide and internationally

(b) explore possible environmental benefits;

Benefits of rebuilding carbon-rich soils extend well beyond the farm gate. Soil carbon is the one single, measurable factor that underpins the solution to multiple natural resource management problems. Improved soil and water quality are the 'key' to catchment health, while the restoration of summer-green perennial groundcover represents the most potent mechanism available for fire retardation, biodiversity enhancement and mitigation of the effects of climate change.

Rebuilding carbon-rich agricultural soils via the adoption of biology-friendly forms of farming based on the restoration of biodiverse summer-green (C4) perennial groundcover, will have multiple long-term benefits for the environment, including

- a 'summer-green' - rather than 'summer-brown' - landscape
- markedly reduced fire risk
- enhanced biodiversity above and below ground
- restoration of ecological integrity
- improved water cycle, especially the 'short' water cycle (condensation as fog and dew)
- enhanced nucleation of atmospheric water vapour, stimulating rainfall
- reduced sedimentation in farm dams, lagoons, wetlands and rivers
- less chemical contamination of waterways - improved aquatic habitat for frogs and fish
- recharge of freshwater aquifers
- restoration of perennial baseflow to rivers and streams
- reduced levels of dryland salinity
- increased number and diversity of beneficial insects and spiders
- increased number and diversity of granivorous and insectivorous birds
- increased number and diversity of grassland reptiles, especially ground-dwelling lizards
- social benefit of aesthetically pleasing landscape
- social benefit of sense of achievement through improved soil health, biodiversity and productivity
- increased generation of oxygen through year-round photosynthesis
- stable soil sequestration of atmospheric carbon
- stable soil sequestration of atmospheric nitrogen
- reduced usage of chemicals toxic to human health

These improvements to both the social and physical environment will be for the benefit of all Victorians, urban and rural alike.

(c) consider methodologies for measurement of the effects of carbon sequestration, including any potential issues associated with the measurement of benefits;

Under the proposed Soil Stewardship Scheme (Appendix K), levels of soil carbon, essential nutrients and soil moisture-holding capacity would be measured in designated sequestration areas on 100 Community Research Farms across Victoria.

A promising innovation in soil carbon measurement has been the calibration of Laser Induced Breakdown Spectroscopy, or LIBS, which provides an easy-to-use portable approach for reliable field assessment of the carbon content of soils (DOE/Oak Ridge National Laboratory, 2009). The simplicity and portability of the LIBS technique for the determination of soil carbon enables greater flexibility than the current laboratory based techniques.

As an alternative to the implementation of a project-based soil carbon offsets scheme, as proposed in Appendix L, incentive payments based on percentage green cover, calculated on an annual basis, would provide a catalyst for change and be highly effective in achieving soil sequestration. Levels of green cover could be remotely sensed and recorded at regular intervals (eg monthly) using satellite imagery. An overlay of spot testing of soil carbon and soil moisture levels would indicate the quantity of atmospheric CO_2 sequestered and atmospheric water vapour retained in soil. A simple incentive scheme of this nature may prove easier to manage and have broader application than intensive testing for soil carbon.

The ‘greening of a brown land’ through the restoration of perennial groundcover would increase soil carbon sequestration, improve soil moisture retention, lessen heat radiation and reduce the atmospheric concentration of CO_2 and water vapour, the two major greenhouse gases. As a bonus, the adoption of perennial groundcover farming techniques would markedly improve the productivity of agricultural land.

Improvements to agricultural productivity and profitability could be assessed by monitoring the financial status of the Community Research Farms.

(d) identify the costs;

It is proposed that ten (10) regional collectives each receive annual funding of $200,000 to administer a cluster of ten (10) Community Research Farms, resulting in the establishment of 100 such farms across Victoria. A reasonable timeline would be for 20 demonstration sites to be established in 2010, adding 30 in 2011 and another 50 in 2012 (Appendix K).

Funds would cover project coordination, educational workshops and field days, purchase of seed and biology friendly fertilisers, contract planting, measurement, recording and publication of soil carbon levels, soil nutrient status and soil moisture-holding capacity.

Community Research Farms would act as ‘community hubs’ for experimentation and demonstration of soil building practices within their region. Participating landholders would receive financial assistance for the establishment of summer-green perennial grasses and/or other groundcover plants and shrubs, preferably as diverse mixtures, on the designated 10ha soil carbon sequestration sites. Regular field days and other activities associated with these sites would enable them to serve as templates for other landholders in the region.

The cost of the proposed Soil Stewardship Scheme over the five-year term of the project would be $7.4 million.

‘Doing nothing’ would cost much more than taking appropriate action.

Failure to restore soil carbon will result in rising input costs for fuel and fertiliser to prop up failing land management regimes, ongoing agricultural emissions from the use of chemical inputs, continued drying out of soils of low-moisture holding capacity (Appendix I), reduced resilience to climatic extremes and the adverse impact of deteriorating soil integrity on food quality and human health (Appendix J).

Soil carbon increases on the 10 ha designated soil sequestration site on each farm could be supported by incentive payments through a project-based soil carbon offsets scheme involving the voluntary carbon market (Appendix L).

The Portuguese Government allocated $13.8 million (Euro 8.5 million) to a soil carbon offsets scheme in June 2009 (Appendix E). The Portuguese scheme involves 400 farmers establishing biodiverse perennial pastures over an area of 42,000 hectares to sequester soil carbon, restore soil health, improve soil-water holding capacity and increase agricultural productivity (Watson 2010).

(e) identify any possible harms or detriments;

There are no known harms or detriments associated with the restoration of carbon-rich agricultural soils via the adoption of natural, biology-friendly forms of farming based on summer-green (C4) perennial groundcover.

(f) identify linkages with the proposed carbon pollution reduction scheme and other relevant Federal Government policies;

In mid-November 2009 the Federal Government announced that a decision on the inclusion of agriculture in the CPRS, originally to be made in 2015, would be brought forward by four years. The Government proposed that agricultural emissions be excluded from the CPRS, while offsets for agricultural abatement, including sequestration in soil, be included.

The Government's planned CPRS was defeated in the Senate in early December 2009. While the Federal Government remains committed to the introduction of an emissions trading scheme, the exact form of this remains unclear.

In late November 2009 the Department of Climate Change released details of the National Carbon Offset Standard to come into effect on 1 July 2010, coinciding with the cessation of the Federal Government's Greenhouse Friendly program. The National Carbon Offset Standard provides Australian businesses, particularly farmers, with the opportunity to develop offset credits for voluntary carbon markets. These opportunities include offsets from increased soil carbon (Department of Climate Change, 2009).

The National Carbon Offset Standard is complementary to, but will operate outside of, the Federal Government's proposed CPRS. A Project-Based Soil Carbon Offset Scheme, as proposed in this submission (Appendix L) could be implemented almost immediately under the provisions of the National Carbon Offset Standard. Partner organisations entering the voluntary carbon market would be confident they were helping restore balance to the climate by supporting natural carbon, nitrogen and water cycles on agricultural land.

The proposed Soil Stewardship Scheme and complementary Project-Based Soil Carbon Offset Scheme represent a cost-effective approach to reducing emissions and mitigating the impacts of climate change while restoring ecological integrity to the landscape. Engaging rural and regional communities, government agencies and business organisations in a scheme focussed on the restoration of soil carbon represents a simple, low-cost and practical approach that makes sound economic and environmental sense, irrespective of the outcome of the CPRS/ETS debate.

(g) identify linkages with existing Victorian Government policies; and

The Victorian Department of Sustainability and Environment White Paper ‘Securing our Natural Future’, released in November 2009, outlines a management framework for building ecosystem resilience, sustaining biodiversity and enhancing ecological processes through support for individuals, institutions and communities over the next 50 years. Key areas of the plan include increasing Government effectiveness, supporting community action, fostering environmental markets and leveraging investment.

The proposed Soil Stewardship Scheme would be consistent with many of the goals outlined in the ‘Securing our Natural Future’ White Paper.

The Stewardship program would also strengthen linkages within existing Landcare networks (some of which are already experimenting with innovative technologies for the restoration of perennial groundcover), Greening Australia, the new Natural Resource and Catchment Authorities, the Department of Planning and Community Development, Department of Regional Development and the Department of Primary Industries.

(h) explore options for the Victorian Government to support the benefits (if any) of soil sequestration.

The Victorian Government could support the multiple benefits of soil sequestration by underwriting a Soil Stewardship Scheme administered by regional collectives, as outlined in Appendix K of this submission. The soil stewardship scheme would represent a cooperative approach to regenerative land management and soil building, based on the development of 100 designated Community Research Farms. The proposed stewardship scheme would involve farmers from a wide range of agricultural regions across Victoria.

Participatory research and extension that promotes the benefits of increased soil carbon and increases the understanding and adoption of changed management practices among Victorian landholders, would result in a vastly more resilient and productive agricultural sector.

As a bonus, the Soil Stewardship Scheme will provide incentive for the adoption of farming practices that actively sequester industrial emissions of carbon dioxide.

……

In closing, some quotes from Prince Charles’ speech at Copenhagen, 15 December 2009.

'The eyes of the world are upon you'

"… the future of mankind can be assured only if we rediscover ways in which to live as a part of nature, not apart from her. .. Furthermore, because climate change is intimately connected with our systemic, unsustainable consumption of natural resources, any decline in the ecological resilience of one resource base or ecosystem increases the fragility of the whole. .. In the last 50 years we have degraded 30% of global topsoil … the climate crisis is the mirror in which we see reflected the combined ecological impact of our industrialised age. … a partial solution to climate change is no solution at all. It must be inclusive and it must be a comprehensive approach - one that strengthens the resilience of our ecosystems. Crucially, it must be embraced by the public, private and NGO sectors, as well as by local communities and indigenous people, while also encouraging individual responsibility. …Just as mankind had the power to push the world to the brink so, too, do we have the power to bring it back into balance."

Literature cited

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DOE/Oak Ridge National Laboratory (2009). Sustainable farming may help maintain healthy climate. *Science Daily*, 20 November, 2009 http://www.sciencedaily.com /releases/2009/11/091119193816.htm

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APPENDIX A: The early Victorian landscape

The writings of George Augustus Robinson

Significant changes to groundcover, soils and waterways have occurred since the colonisation of what is now Victoria began in earnest in 1835.

A window to the life and times of Victorian landholders in the mid-1800s can be found in the 'Journals of George Augustus Robinson' edited by Gary Presland, published as part of the Records of the Victorian Archaeological Survey (Presland 1977).

Robinson was the Chief Protector of Aborigines in Victoria in the 1840s. His daily journal contains fascinating insights into aboriginal culture - and an extraordinarily account of the landscape he travelled through while undertaking his work.

Almost every page of Robinson's journal makes reference to 'green grass' - even in the height of summer, with daily temperatures frequently above 100 degrees Fahrenheit.

For example Friday 10 January 1840 "The country through which we travelled today consisted of green hills and valleys with a verdure of transparent green. The sun was hot and the bright green of the grass, contrasted with the sombre foliage of the trees, had a delightful appearance. The roads and soil was good and the country on either side of the road as far as the eye could scan was truly luxuriant."

Friday 24 January 1840 "Followed round by the creek about a mile beyond Mt Campbell on the west side, returned a mile and then crossed the creek opposite the mount and rode over some stony hills, and ascended the mount. The day was fine and view clear. Rode half way up, then tethered our horses and walked to the summit. To the N. and N.W. as far as the eye could scan was a boundless plain and an ocean like appearance. Due N., distant about 10 miles from Mt Campbell, observed extensive grassy plains extending in the direction of the Goulburn River. Mr Hutton has been on the plains and represents the soil to be a deep rich mould. He thrust [a] stick two feet into the soil and it was of [the] same description, and yet deeper. …The country to the S. and west good grassy country, undulating and extending as far as the eye could reach.. …. Asked Mr Hutton if he ever kept a meteorological journal. Said he did once but it was for near 9 months all fine weather, and he got disgusted with putting down ditto, ditto, it was nothing but ditto".

(Note: Mt Campbell is today known as Mt Camel).

The important point to emerge from colonial records is that the summer-green perennial grasslands that greeted early settlers had resulted in the formation of deep, rich soils despite long, hot, dry summers.

There are references throughout Robinson's journal to vast carpets of colourful flowers and creepers, aboriginal women with 'large heaps of murnong' (yam daisy tubers), the plentiful - and large - fish, eels and crayfish in the rivers. Many of the waterways were described as rush-lined chains of ponds.

There are also references to patches of trees and forests in Robinson's journal but it is obvious that the early settlers in the medium to low rainfall areas of Victoria did not need to clear trees for their sheep and cattle runs or for their small scale cropping (wheat, barley, vegetables). The woody vegetation referred to by Robinson was principally native cherry [Exocarpus], honeysuckle [Banksia] and oak [Casuarina]. Many of the hills were described as treeless or with only scattered trees. The grassy valleys and plains were luxuriant, verdant meadows - even in the height of summer.

Artworks exhibited in the Colonial Australia section of the National Art Gallery in Canberra match with the writings of Robinson and other hand-written accounts from the mid-1800s. The grasses in the paintings (all of which were native species, it being very early in the settlement period) are lush and green and many of the hills are depicted as treeless.

Why did everything change?

Paradise lost: the demise of rich grasslands, pristine waterways and fertile soils

i) **Burning.** Contrary to common belief, the scale, intensity and frequency of burning of grasslands increased dramatically with the advent of European colonisation. Robinson makes frequent references to the wide-scale annual burning by the early settlers in his writings (Presland 1977).

Burning followed by grazing of green pick diminishes plant root reserves, ultimately leading to loss of ‘softer’ species. In seasonal rainfall environments, a combination of burning and set-stocking moves the composition of the vegetation from yearlong green perennial groundcover towards short lived annual grasses and weeds and fire tolerant woody species such as Eucalyptus and Acacia.

While it is true that aboriginal people burned grasslands, their ‘mosaic patch burning’ methods were cool burns, undertaken when conditions were mild and while grasses were green. Wide-scale and repeated hot burning by Europeans contributed to the rapid demise of the dominant vegetation of warm-season grasses and destroyed precious surface mulch.

ii) **Loss of habitat for small ground-foraging mammals.** The combined effects of burning and inappropriate grazing in the early settlement period resulted in loss of habitat for small ground-foraging native mammals such as bettongs, bandicoots, potoroos, native rats and mice. These small mammals were extremely abundant in colonial days. They were keystone species for landscape health, aerating soil, burying organic matter and ‘planting’ seeds of grassland species, as they turned the soil in their quest for fungi, insects and worms (Claridge 1996). Small mammals were not grass eaters, but their diet included newly emerging seedlings of woody plants, which were actively sought.

Since European settlement over half of Australia’s small native mammals have become extinct or had their distributions markedly reduced.

iii) **Change in type of vegetative cover.** Due to a complex of interacting factors including the frequency and extent of burning, the imposition of heavy and continuous grazing and the loss of ground foraging native fauna, there was an explosion in woody vegetation across the Victorian landscape during the mid to late 1800s. This resulted in a misleading emphasis on trees when people tried to recall the nature of the original landscape.

iv) **Soil loss.** Although not Victorian data, a key insight into the rate of soil loss with the advent of European settlement comes from a study of sedimentation rates in Little Llangothlin Lagoon, on the Northern Tablelands of NSW.

In their paper ' Catchment-wide soil loss from pre-agricultural times to the present: transport- and supply-limitation of erosion' Gale and Haworth (2005) report that immediately prior to the arrival of Europeans in the catchment of Little Llangothlin Lagoon, the average erosion rate was **25 tonnes** per square km per annum [2.5t/ha/yr]. The disturbance consequent upon the arrival of Europeans in the catchment had a massive and near-instantaneous impact, with a mean rate of erosion in the 25 year period from 1836 -1861 of **1360 tonnes** per square km per annum [136t/ha/yr]. That is, the rate of erosion increased by a factor of over 50 with the arrival of European settlers and the loss of groundcover through unmanaged grazing.

Gale and Haworth (2005) calculated that 85% of post-contact erosion occurred in the first 25 years of European settlement. Significantly, a majority of the displaced soils in the early settlement period consisted of low bulk density humus-like material with an organic matter content of around 7%.

From 1861, there was a sudden transition to a lower, constant rate of erosion of 52 tonnes per square kilometre per year [5.2t/ha/yr]. The authors concluded that the high rates of early colonial soil loss had almost entirely depleted the catchment of erodible material, with the result that erosion moved from a transport-controlled regime to one that was limited by the rate at which catchment material was made available for transport.

The situation described by Gale and Haworth (2005) for the Northern Tablelands of NSW was mirrored in many other parts of Australia, including Victoria.

Billis and Kenyon (1930) provide a detailed account of the pastoral developments that began with the shipping of 55,000 sheep from Van Diemen's Land to Port Phillip in 1835. "By 1841 there were 20,416 people, 1,090,00 sheep, 78,000 head of cattle. 4,881 acres of cultivated land and 2,800,000 pounds of wool exported" (Billis and Kenyon, 1930). Sheep numbers roughly doubled every decade until the late 1800s.

The impact of unmanaged grazing on native grasslands in the Wannon country south-west of Horsham was recorded by John Robertson in 1853. When he first arrived, Robertson counted 37 different species of perennial native grasses on his run. Sheep were often difficult to find in the long growth. Within two years, Robertson observed that bare ground caused by overgrazing gave way to numerous deep erosion gullies across his land, accompanied by the emergence of saline springs (Billis and Kenyon, 1930).

The loss of summer-green perennial groundcover due to unmanaged grazing in Victoria's early settlement period resulted in large quantities of fertile topsoil being transported to fill wetlands, lagoons, streams and rivers in all regions of the colony.

The changes to soils were dramatic and sudden.

Fortunately, they are reversible.

Literature cited

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APPENDIX B: Soil carbon levels in the early settlement period

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 times higher than in Victorian soils today (Appendix C). It is also worth noting that Strzelecki's samples were not from virgin soils. They were collected from paddocks that were already being farmed. It is therefore likely that the original organic matter contents of these soils were even higher than recorded.

The soil test data from Strzelecki is consistent with the writings of early settlers. For example, the 1840s journal of George Augustus Robinson (Appendix A) described Victorian soils in the regions to the north and north-west of the Port Phillip settlement as being extremely fertile and productive in the mid-1800s.

A Faculty of Agriculture was established at the University of Melbourne in 1905, more than 100 years from the time of the first European settlement at Port Phillip Bay in 1803. Much had changed in the intervening period, not the least of which was the status of Victorian soils. Indeed, the abundant summer-green perennial grasslands and deep, carbon-rich, friable soils described by early pastoralists had long since disappeared.

Even under most current 'best management' practices, soils continue to lose their organic carbon. The legacy for current landholders is that input costs for the agricultural sector are rising, with no commensurate increase in productivity. This situation could be reversed by the restoration of landscape function through a return to appropriately managed biodiverse perennial groundcover.

Literature cited

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)

APPENDIX C: Soil carbon in Victoria today

As reported in Appendix A, extensive tracts of perennial grasslands and open grassy woodlands occurred in central, northern and western Victoria when pastoralism first commenced in the mid-1800s. In the height of long dry summers, groundcover remained green. The demise of this productive yearlong green groundcover, with its ability to respond to rain at any time, can be linked to many of the 'problems' now facing the agricultural sector.

There is a close correlation between soil sequestration and the quality of groundcover

Periodically bare soils generally contain only half the organic carbon of similar soils in the same region under pasture (for example, see table below). As a result, the periodically bare soils have poorer structure, higher rates of soil erosion, lower soil water-holding capacity and reduced nutrient levels.

Low, normal and high ranges for average soil organic carbon levels (% by weight) in crop and pasture soils in low rainfall (< 500mm) and high rainfall (>500mm) regions, Victoria

	Low rainfall (< 500 mm)		High rainfall (> 500 mm)	
	Crop	**Pasture**	**Crop**	**Pasture**
Low	0.9	1.7	1.45	<2.9
Normal	0.9 - 1.4	1.7 - 2.6	1.45 - 2.9	2.9 - 5.8
High	>1.45	>2.6	>2.9	>5.8

Source: Brown A.J., Fung K.K.H. and Peverill K.K.I. (1980). A manual on the soil testing service provided by the Division of Agricultural Chemistry, Department of Agriculture, Victoria, Technical Report Series No 34.

The decline in soil carbon due to low levels of groundcover has created a ready-made sink. Carbon losses could be reversed by the reinstatement of living groundcover, using techniques such as Pasture Cropping (Appendix D), being successfully trialled in Victoria by several farming and community groups.

The data in the above table indicate that a change from periodically bare soil, to pasture covered soil, has the potential to increase soil carbon levels by around 1% in low rainfall regions and up to 3% in higher rainfall regions.

An increase of 1% in the level of soil carbon in the 0-30cm soil profile would equate to the sequestration of 154 tCO_2/ha if an average bulk density of 1.4 g/cm^3 is assumed, while an increase of 3% in the level of soil carbon in the 0-30cm soil profile would equate to the sequestration of 462 tCO_2/ha.

Innovative (frontier-type) land management technologies that promote soil building are more productive and less expensive than conventional farming practices that deplete soil carbon. When biology friendly fertilisers and continuous sequestration (via techniques such as Pasture Cropping) are used in place of conventional fossil-fuel based fertilisers in traditional bare fallow systems, the carbon footprint is reversed (that is, more carbon is sequestered than emitted).

On average, 12 tonnes of topsoil are eroded for every tonne of wheat currently produced in Australia. Greater losses are experienced on more fragile soils. For example, over 200 tonnes of topsoil are eroded for each tonne of wheat produced in some parts of the Wimmera region in western Victoria.

No civilisation can survive the physical destruction of its primary resource base - the soil.

Reversing the effects of land use change

Guo and Gifford (2002) reviewed data from 74 publications on the influence of land use change on soil carbon levels. Analysis of the literature showed that soil carbon levels declined when land use changed from pasture to crop but increased again when land use was reversed from crop to pasture.

The authors concluded "Wherever one of the land use changes decreased soil carbon, the reverse process usually increased soil carbon and *vice versa*" (Guo and Gifford, 2002)

Putting the carbon back

The major change to the Victorian landscape has been the loss of yearlong green perennial groundcover, very early in the settlement period, followed shortly thereafter by massive soil degradation and losses of soil carbon.

There are no current Victorian Government policies that focus specifically on reversing the process, that is, restoring summer-green perennial groundcover and rebuilding topsoil at local, catchment, regional or state-wide scales.

This submission proposes a Soil Stewardship Scheme (Appendix K) as a way forward.

Literature cited

Guo, L. B. and Gifford, R. M. (2002). Soil carbon stocks and land use change: a meta analysis. *Global Change Biology*, **8**: 345-360

Brown A.J., Fung K.K.H. and Peverill K.K.I. (1980). A manual on the soil testing service provided by the Division of Agricultural Chemistry, Department of Agriculture, Victoria, Technical Report Series No 34.

APPENDIX D: How does atmospheric carbon get into soil?

The 'soil sequestration solution' to removing excess carbon dioxide from the earth's atmosphere is being overlooked because current mathematical models for soil carbon dynamics fail to include the primary pathway for natural soil building.

The process whereby gaseous carbon dioxide is converted to stable soil carbon has been occurring for millions of years. Indeed, it is the only mechanism by which friable, porous topsoil can form.

Building soil carbon requires green plants and soil microbes.

There are 4 steps to 'turning air into soil'

i) Photosynthesis
ii) Resynthesis
iii) Exudation
iv) Humification

i) Photosynthesis

The miracle of **photosynthesis** takes place in the chloroplasts of green leaves. It is a two-step endothermic reaction (ie a **cooling process)**. Incoming light energy (sunlight) is captured and stored as biochemical energy in the form of a simple sugar - glucose ($C_6H_{12}O_6$), using carbon dioxide (CO_2) from the air, and water (H_2O), from the soil. Oxygen is released to the atmosphere.

Photosynthesis requires 15MJ of sunlight energy for every kilogram of glucose produced. If the same 15MJ of incoming light energy makes contact with a bare surface, such as bare ground, it is reflected, absorbed or radiated - as **heat**, usually accompanied by moisture. Thus the respective area of the earth's surface covered by either actively growing crops and pastures, or bare ground, has a significant effect on local, regional and global climate.

ii) Resynthesis

Through a myriad of chemical reactions, the glucose formed during photosynthesis is resynthesised to a wide variety of carbon compounds, including carbohydrates (such as cellulose and starch), proteins, organic acids, waxes and oils. Carbon atoms can link together to form long chains, branched chains and rings, to which other elements, such as hydrogen and oxygen, can join.

The energy captured during photosynthesis and stored in carbon compounds serves as 'fuel' for life on earth. Carbohydrates in grasses, fruits, vegetables and grains provide energy for animals and people - and carbon stored in previous eras as 'fossil fuels' (hydrocarbons) such as coal, oil and gas - provides energy for vehicles, machinery and industry.

iii) Exudation

Around 30-40% of the carbon fixed by grass plants during photosynthesis can be exuded into soil to form a microbial bridge - that is - to nurture the microbes that enhance the availability of essential plant nutrients. In this way, actively growing crops and pastures provide 'fuel' for the soil engine.

Carbon compounds and the microbial populations they support are essential to the creation of topsoil from the structureless, lifeless mineral soil produced by the weathering of rocks. However, exudation does not occur to any significant extent if high rates of water-soluble nutrients such as phosphorus and/or nitrogen have been applied. These high analysis fertilisers disrupt the sensitive biochemical signalling mechanisms between plants and soil microbes.

Provided the microbial bridge is intact, organic carbon additions are governed by the volume of plant roots per unit of soil and their rate of growth. The more active green leaves there are, the more healthy roots there are, the more carbon is exuded. The breakdown of fibrous roots pruned into soil through rest-rotation grazing can also be an important source of carbon in soils.

Fig. 1. The dark coloured carbon sequestered around the roots of perennial grasses is readily observed in light coloured soils. (Photo Christine Jones)

iv) Humification

Sequestering organic carbon in soil is one thing. Keeping it there is another. Soil carbon moves between various ‘pools’, some of which are short-lived while others may persist for thousands of years. The active sequestration of atmospheric carbon is most effective when combined with land management practices and biology friendly fertiliser strategies that enhance the soil food-web and foster the conversion of relatively transient forms of organic carbon to more stable forms.

If soil is of high ecological integrity, soil microbes, especially fungi, resynthesise and polymerise labile carbon (mostly exuded from plant roots) into high molecular weight stable complexes, referred to collectively as humic substances. Humus, a gel-like substance that forms an integral component of the soil matrix, is the best known of the long-lived stable organic fractions.

Humus is composed of large, complex molecules made up of carbon, nitrogen, soil minerals and soil aggregates. It is an inseparable part of the soil matrix that can remain intact for hundreds, sometimes thousands, of years.

Humified carbon differs physically, chemically and biologically from the labile pool of organic carbon that typically forms in agricultural soils. Labile organic carbon arises principally from biomass inputs (such as crop residues) which are readily decomposed. Conversely, most humified carbon derives from direct exudation or transfer of soluble carbon from plant roots to mycorrhizal fungi and other symbiotic or associative microflora.

Once carbon is sequestered as humus it has high resistance to microbial and oxidative decomposition.

The humification process does not occur in most broadacre agricultural production systems, due to lack of the year-round green leaves required to fuel the photosynthetic process and maintain vital components of the soil food-web. In the absence of humification, the carbon exuded from plant roots (or added to soil as plant residues, manure or compost) simply oxidises and recycles back to the atmosphere as carbon dioxide.

Humic substances have significance above and beyond the relatively long-term sequestration of atmospheric carbon. They are extremely important in terms of pH buffering, inactivation of pesticides and other pollutants, improved plant nutrition and increased soil-water-holding capacity. By chelating salts, humic substances can also effectively ameliorate the symptoms of dryland salinity. Increasing the natural rate of humification in soil therefore has highly significant benefits for the health and productivity of agricultural land.

Maintaining soil structure

‘Aggregation’ is part of the humification and soil carbon building process. It is essential for maintaining soil structure. Glues and gums produced by microbes in the rhizosphere enable the formation of peds or lumps (which can be seen with the naked eye, often attached to plant roots). The presence of these aggregates creates macropores (spaces between the aggregates) which markedly improve the infiltration of water. After rain, less water sits on the soil surface and waterlogging is reduced. As structure continues to improve, smaller and smaller aggregates are formed, along with soil mesopores and micropores. Reinstatement of the complete range of aggregate and soil pore sizes dramatically improves soil function, aeration, levels of biological activity and resilience.

Soil structure is not permanent. Aggregates made from microbial substances are continually breaking down and rebuilding. An ongoing supply of energy in the form of carbon from the rhizosphere exudates of actively growing plant roots will maintain soil structure. If soils are left without a cover of green plants for long periods they become compacted - or in the case of light soils - blow or wash away.

Under conventional cropping or set-stocked annual pastures, the stimulatory exudates produced by short-lived winter-active pasture species are negated by bare earth over summer. The inevitable result is a decline in levels of soil carbon, soil structure and soil function.

Soil building requires green plants and soil cover for as much of the year as possible. A mix of warm-season and cool-season perennials enables response to rain at any time. In grazing enterprises, rest-rotation management is absolutely essential. For broadacre cropping, the presence of out-of-season groundcover ensures stability, long term productivity and soil building - rather than soil destruction.

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

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

Adapting farming to climate change

Several members of the House of Representatives Standing Committee on Primary Industries and Resources (Fig.1) recently visited Australian Soil Carbon Accreditation Scheme (ASCAS) sites in Western Australia as part of the Federal Government inquiry into ‘Adapting Farming to Climate Change’.

Fig. 1. Bill Currans (Program Manager, Northern Agricultural Catchments Council), Tony Windsor (Federal Member for New England), Christine Jones (Australian Soil Carbon Accreditation Scheme), Tim Wiley (WA Department of Agriculture and Food), The Hon Dick Adams (Federal Member for Lyons and Chair, House of Representatives Standing Committee on Primary Industries and Resources), Barry Haase (Federal Member for Kalgoorlie), Alby Schulz (Federal Member for Hume), Keith Tunney (property owner), Bob Wilson (Vice President Evergreen Farming Group) and David Ferris (WA Department of Agriculture and Food) pictured during a visit to Keith Tunney’s property east of Dongara, WA, as part of the House of Representatives Standing Committee on Primary Industries and Resources inquiry into ‘Adapting Farming to Climate Change’. (Photo Rob Grima).

The Australian Soil Carbon Accreditation Scheme works closely with the Northern Agricultural Catchments Council (NACC), the 600-member Evergreen Farming Group and Tim Wiley, co-author of Moore, Sanford and Wiley 'Perennial Pastures for Western Australia'. These groups have been highly successful in establishing summer-green (C4) perennial pastures as a productive base for broadacre cropping and livestock grazing enterprises in the winter rainfall mixed farming regions of Western Australia.

Pasture Cropping

The practice of Pasture Cropping, where an annual crop is grown out-of-phase with perennial pasture, was developed by Darryl Cluff and Colin Seis (Cluff and Seis, 1997). Pasture Cropping can result in higher rates of soil building than occur under perennial pasture alone. This is considered to be the result of year-round transfer of soluble carbon to the root-zone and the maintenance of the humification process in the non-growth period of the perennial.

Established summer-green perennial grasses can be oversown with annual grain crops such as wheat, barley, triticale, oats, lupins, chickpeas or canola during their dormant winter phase (Fig. 2). For grazing purposes, mixtures of several crops (eg cereals and legumes) can be sown simultaneously (cocktail cropping) to enhance biodiversity and animal nutrition.

Fig. 2. Pasture cropped paddock on Keith Tunney's property east of Dongara, WA, showing the summer-green perennial pasture beneath a harvested strip of winter oats, sown between alleys of tagasaste. The House of Representatives Standing Committee on Primary Industries and Resources visited this property in September 2009 as part of the Federal Government inquiry into Adapting Farming to Climate Change (Photo Tim Wiley).

Perennial pasture paddocks can be grazed immediately the crop has been harvested - and can continue to be grazed over summer. In addition to providing livestock feed and erosion control, the areas sown down to perennial pastures actively sequester soil carbon. In the absence of the perennial grasses shown in Fig. 2, soils beneath annual crops in the Western Australian cropping belt (as in Victoria) would be bare over summer - and losing soil carbon.

Over time, mixtures of grasses and shrubs in alleys such as that depicted in Fig. 2. develop long-lived mycorrhizal guilds (Leake *et al.* 2004). In addition to enhancing soil sequestration, mycorrhizal associations provide many other benefits to plants, including improved mineral nutrition, enhanced disease resistance, higher water use efficiency and greater tolerance to environmental extremes (Allen 2007).

Under some conditions, the growth of an annual crop planted out-of-phase with a perennial pasture can be equal to, or better than, the growth of an annual crop planted alone. This may reflect higher levels of biological activity, improved soil structure, enhanced nutrition, water balance advantages (such as hydraulic lift and hydraulic redistribution) and microclimate benefits attendant upon co-existence with perennials.

Improved ecological integrity has flow-on benefits for food quality and human health, which could be assessed by way of a “Soil Integrity Index’ and food labelling system (Appendix J).

Knowledge base for restoring perennial groundcover

Due to their specialised photosynthetic pathway, summer-green (C4) perennial grasses grow better under high temperatures than under low temperatures. They perform well on their own or in mixtures. Summer active C4 perennial grasses are particularly suited to alley-farm situations, sown into bays between rows of shrubs such as saltbush, rhagodia, acacia or tagasaste. The choice of both grass and shrub species will depend on prevailing environmental and ecological conditions.

A newly released publication, ‘Prospects for Perennials’ by Dr Sarita Bennett, University of Western Australia and Future Farms CRC researcher, provides a useful guide for the successful incorporation of perennials into mixed farming systems in the southern half of Australia (Reading 2009). The book includes tables of the most suitable perennial grasses, legumes and herbs for each of 12 regions in southern Australia, along with information on rainfall, soil and environmental conditions required for each species, plus case studies and a linked website providing guidelines for sowing and management.

There is also a GRDC Driving Agronomy 2010 audio compact disc on perennial pastures for the southern region (Reading 2009).

Barriers to adoption

It is not lack of information, but rather, technical and financial constraints, that impose the main barrier to the adoption of perennials in farming systems. Hence the importance of a Soil Stewardship Scheme, as proposed in this submission, supporting change on 100 designated Community Research Farms throughout regional Victoria. Once the benefits of summer-green perennials have been demonstrated, wider adoption will take place for economic and productivity reasons. The active soil sequestration of atmospheric carbon will occur naturally as a bonus.

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APPENDIX E: Soil sequestration rates under perennial groundcover

A change from annual to perennial groundcover can double levels of carbon sequestered in topsoil in a relatively short time. This is not surprising. Photosynthesis, the most important driver for soil building, occurs for a much greater portion of the year where groundcover is perennial, particularly where plants are summer-green. Further, the permanent presence of a living host provides a reliable supply of soluble carbon and suitable habitat for colonisation by mycorrhizal fungi (Appendix H).

Studies undertaken on degraded farmland in Alentago, Portugal, in the period 2001 to 2004, recorded soil sequestration rates of 10.42tCO_2/ha/yr (soil organic matter content increased from 0.55% to 1.6%) and 12.8 tCO_2/ha/yr (soil organic matter content increased from 0.8% to 2.08%), where perennial pastures had been established, via ploughing or minimum tillage, respectively (Watson, 2010).

Subsequent data collected as part of the Portuguese Terraprima soil carbon project (Watson 2010) demonstrated the potential of sown perennial pastures to sequester atmospheric carbon over a 10 year period (Fig.1, below).

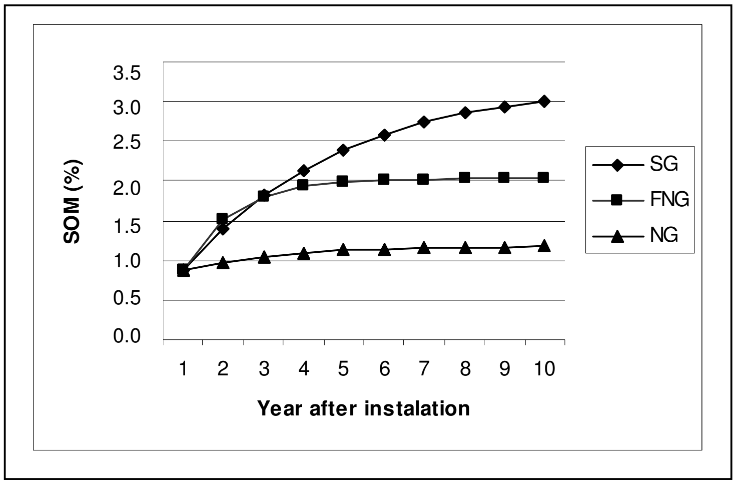

Fig. 1. Accumulation of soil organic matter (SOM), shown as percentage by weight, in soils under three pasture types. SG = sown perennial pasture; FNG = fertilised annual pasture; NG = unfertilised annual pasture (from Watson 2010).

Central and southern Portugal experience a mediterranean-type climate very similar to many parts of Victoria.

The Portuguese Terraprima data illustrated in Fig.1 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%. If this increase was confined to the top 10cm of soil it would equate to the sequestration of around 6.3tCO_2/ha/yr. If the increase extended to the top 20cm of soil (a more likely scenario under perennial pasture) it would equate to 12.6 tCO_2/ha/yr. If the increase applied to the top 30cm of soil it would equate to the sequestration of 18.9 tCO_2/ha/yr.

The Portuguese Government soil carbon offsets project, commenced in July 2009, aims to sequester 0.91 million tonnes of CO_2 in the soil beneath 42,000 hectares of sown diverse perennial pasture 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 (45 degrees latitude would place these sites well south of Tasmania), the USDA-ARS research, averaged across 10 sites (encompassing a 930 x 230 km range through North and South Dakota and Nebraska) recorded average soil carbon sequestration rates of 4tCO2/ha/yr in the 0-30 cm soil profile and 10.6tCO2/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 80tCO2/ha.

It's unfortunate that the carbon in the deeper soil profile was not recorded at the Bristol site, which recorded the highest sequestration rates in the 0-30 cm increment. At the three sites where carbon was measured to 120 cm, the USDA research found relatively high sequestration rates below 30 cm. The average sequestration rate was higher for the 30-60 cm increment than for the 0-30 cm increment (18.2tCO2/ha vs 16.5tCO2/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.

Over the 10 sites, the average sequestration rates for 0-10, 10-20 and 20-30 cm profiles respectively, were 3.05, 5.03 and 11.85 tCO2/ha over five years. That is, the sequestration rate generally increased with depth - beginning with 3tCO2/ha near the surface and reaching almost 12tCO2/ha in the 20-30cm increment. Although this pattern was not followed at all sites, it is possible these data highlight the fundamental difference between the carbon resulting from rhizosphere exudates in a healthy living ecosystem and the labile carbon which forms close to the soil surface in essentially 'dead' minimum till soils - or set-stocked annual pastures.

There were virtually no 'biomass inputs' to soil in these trials, as all aboveground material was removed for bioenergy. This suggests the liquid carbon pathway (Appendix D) as the primary mechanism for soil building.

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APPENDIX F: Plant nutrition benefits of soil sequestration

Tim Wiley, when with the WA Department of Agriculture and Food, determined levels of available plant nutrients in soil directly beneath the crowns of Gatton Panic, one of the grasses in the 'Evergreen mix' of summer-active perennials currently being established in the winter-dominant rainfall regions of WA for soil stabilisation and year-round livestock production. Wiley (2009) found the availability of phosphorus (P) increased by 338%, potassium (K) increased by 341% and sulphur (S) increased by 293% due to the presence of Gatton Panic. These differences in nutrient availability were directly correlated with levels of soil carbon (Table 1).

Table 1. Soil nutrient levels (0-30cm) from between and within Gatton Panic crowns, Binnu, WA, May 2009

	Bare soil	Beneath plants	Difference
Organic carbon (%)	0.24	1.04	433% increase
Phosphorus (Colwell ppm)	21	71	338% increase
Potassium (Colwell ppm)	44	150	341% increase
Sulphur (ppm)	2.7	7.9	293% increase
Nitrate N (ppm)	4	2	50% decrease
Ammonium N	2	3	50% increase
pH (CaCl)	5.8	7.1	1.3 unit increase
pH (water)	6.4	7.8	1.4 unit increase

Source: Tim Wiley, WA Department of Agriculture and Food (Wiley 2009)

There has been a widely publicised 'myth', actively promoted in some scientific circles, that increasing the level of soil carbon in agricultural soils will reduce the availability of important plant nutrients, hence requiring expensive additions of synthetic fertiliser (Passioura *et al.* 2008). This view cannot be substantiated in practice.

Time series data from around Australia clearly show that as soil carbon levels increase, the availability of macronutrients such as P, Ca, K and S and micronutrients such as Cu, Zn, Fe, Mo, B improve. There is also a tendency for pH to normalise and CEC to increase.

Interestingly, at the same time as the availability of important plant nutrients increases, the availability of less desirable elements such as sodium (Na) and aluminium (Al) declines.

Improvements in soil health under perennial groundcover provide an insight into the way grassland communities and microbial communities functioned naturally in the past, and can function again in the future, given the opportunity. It's up to the human community to understand these linkages and to nurture them.

Indeed, where perennial groundcover is inadequate, soils frequently deteriorate, leading to problems with structure, sodicity, waterlogging, mineral imbalance, salinity, erosion and colonisation by weeds.

Perennial grasses, mycorrhizal fungi and soil nitrogen

A common feature of soil chemistry under perennial grasses is a change in the form in which nitrogen occurs. The higher the ecological integrity of soil the more noticeable this effect. Data presented in Table 1 (above) indicate that while levels of P, K and S tripled under the perennial grass, levels of mineralised nitrogen (nitrate and ammonium) were low. There was a reduction in nitrate levels and an increase in ammonium levels, but neither would be considered adequate for plant production. A simple calculation of biomass produced and the protein content of this biomass shows that considerable quantities of N have been accessed by the perennial grasses. This has clearly not been via the nitrate or ammonium pathways.

If plants are mycorrhizal, they don't require nitrogen in a mineralised form, that is, in the form of nitrate or ammonium. Mycorrhizal fungi have to convert mineralised N to glutamate to transport it, which represents an energy cost. These microbes preferentially transport N in an organic form, for example, as amino acids such as glycine and glutamine (Leake *et al.* 2004).

Utilisation of organic N by mycorrhizal fungi closes the N cycle and prevents soil acidity, as well as preventing volatilisation of N to the atmosphere and leaching to aquifers and rivers.

Nitrogen fertilisation inhibits soil sequestration

The ‘myth’ that building soil carbon requires expensive fertiliser inputs (Passioura *et al.* 2008) could not be further from the truth. The widespread use of high analysis fertilisers are one of the main reasons that soil carbon fails to increase substantially in conventional farming regimes (Leake *et al.* 2004).

Data from North America’s longest running field experiment on the impacts of farm production systems on soil quality has revealed that high nitrogen (N) inputs in conventional cropping systems deplete soil carbon and reduce soil water-holding capacity (Khan *et al.* 2007).

To understand why yields were lower for plots that received the most nitrogen, University of Illinois team leader Saeed Khan and his colleagues analysed soils to identify changes in organic carbon that had occurred since synthetic nitrogen fertilisation began in 1955. The research team discovered that after five decades of massive inputs of crop stubbles ‘ranging from 90 to 124 tons per acre’, all of the added carbon had disappeared and there had been a net decrease in the initial soil carbon level of an average 4.9 tons per acre. Regardless of the crop rotation, the losses in soil carbon increased with higher nitrogen rates (Larsen 2007).

The authors concluded that adding high rates of N stimulated the decomposition of organic matter in soil, releasing carbon to the atmosphere. This conclusion is in agreement with numerous long-term baseline data sets from chemical-based cropping systems involving a wide variety of soils, geographic regions, and tillage practices around the world (Mulvaney *et al*. 2009).

High levels of nitrogen fertiliser are detrimental to microbial diversity, dilute the nutrient density of food, reduce soil carbon, deplete soil nitrogen (ironically), reduce water quality, require large quantities of natural gas during manufacture (the Haber-Bosch process is an energy-intensive conversion of highly inert N_2 to highly reactive NH_3), cost farmers a great deal of money and contribute much more significantly and directly to the greenhouse effect than previously thought.

The loss of organic nitrogen and organic carbon as the result of high N inputs decreases soil productivity and the agronomic efficiency (kg grain kg^{-1} N) of fertiliser (Mulvaney *et al*. 2009). This has been implicated as the underlying cause of widespread reports of yield stagnation or even decline for grain production.

Conversely, crop production systems that favour the kinds of microbes associated with humification, such as mycorrhizal fungi (Appendix H) require much lower N inputs, sequester carbon, improve soil integrity, restore water quality and enhance farm profitability.

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APPENDIX G: Grassland as habitat

Landholders throughout Australia adopting land management regimes that promote the diversity, health and vigour of perennial groundcover have observed an increased abundance and diversity of grassland and grassy woodland birds.

Birds are generally at the top of the food chain and hence are good indicators of soil health.

Increasing the number of trees in the landscape cannot of itself improve bird numbers, unless there is also an increased food supply.

All life above ground depends on the productivity of soil. Appropriately managed perennial grasslands provide a wide range of nutritious foods including seeds, insects, spiders, frogs and lizards, supporting a diverse array of granivorous, insectivorous and omnivorous birds.

It is also important to look beneath the soil surface when assessing habitat, as over 90% of terrestrial diversity is **in** the soil.

Around 12.5 million hectares of land are devoted to agricultural production in Victoria. The soil has deteriorated and continues to deteriorate on much of this area. While the landscape and productivity losses accompanying soil degradation are well documented, loss of food supply for other life forms is a factor that is often overlooked.

Restoring diverse perennial grasslands across regional Victoria, as the basis for agricultural production, would also restore valuable habitat, integrating production and conservation in space and time. Other benefits would include improved aggregate stability, reduced erosion, reversal of soil structural decline, reduced salinity, sodicity, acidity, significantly improved soil water-holding capacity, higher nutrient availabilities and a reduction in weed, pest and disease problems.

Grass/crop/shrub mixtures

The greatest ecosystem benefit from the restoration of perennial groundcover would derive from a diverse mix of perennial grasses and legumes, grown in wide bays within alleys of mixed shrubs. Although there is clear evidence that annual crops, perennial pastures and shrubs can benefit from being appropriately combined in a mutualistic fashion, it will take time to ascertain the best species combinations for the varying soils encountered across the agricultural regions of Victoria. Dr Sarita Bennett's newly released publication 'Prospects for Perennials' (Reading 2009) will assist greatly in this regard.

Experimenting with various mixes of perennial groundcovers and shrubs, nourished with biofertilisers such as compost teas and worm leachates (produced on-farm or in specialist regional collectives), will be one of the key roles of the farming groups associated with each of the Community Research Farms and associated Satellite Farms (Appendix K). Habitat reconstruction will be slow initially, but as more and more landholders join the network of Satellite Farms, transforming the Victorian landscape from summer-brown to summer-green, bird numbers and other indicators of ecosystem health will noticeably improve.

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APPENDIX H: Mycorrhizal fungi - powerhouse of the soil

The soil foodweb constitutes an underground engine of fundamental significance to plant productivity. Mycorrhizal fungi play a key role in the functioning of this foodweb, drawing down atmospheric CO_2 as dissolved organic carbon (DOC) and providing much-needed energy for the soil ecosystem. Mycorrhizal fungi also improve aggregate stability, enhance soil structure, build stable soil carbon, improve plant water use efficiency and increase the efficiency of utilisation of important nutrients such as phosphorus, sulphur and nitrogen.

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

What are mycorrhizas and how do they work?

Vesicular arbuscular mycorrhizas (VAM) are 'obligate fungal symbionts', meaning they must form an association with living plants. They acquire their energy in liquid form, as dissolved organic carbon, siphoned directly from actively growing roots. Mycorrhizal fungi cannot obtain energy in any other way. They have mechanisms enabling them to survive while host plants are dormant but cannot survive if host plants are completely removed.

Mycorrhizal fungi produce thin, hair-like threads of cytoplasm (hyphae) with a hyphal tip at each end. One tip enters a plant root and the other tip explores the soil matrix. Although the hyphae are small in diameter (usually less than 10μm), the mycelial network can extend across many hectares (Allen 2007). Thus mycorrhizas are not really microorganisms, but rather, macroorganisms packaged into microscopic units (Allen 2007).

Mycorrhizal fungi have a fan-shaped architecture, with long runner hyphae dichotomously branching into networks of narrower and narrower absorbing hyphae. There can be over 100 hyphal tips at the distal ends of each runner (Allen 2007). Importantly, these networks extend from the root system into the bulk soil, well beyond the zone occupied by the roots and root hairs. The absorptive area of mycorrhizal hyphae is approximately 10 times more efficient that that of root hairs and about 100 times more efficient than that of roots.

An amazing symbiotic relationship

Plants colonised by mycorrhizal fungi can grow around 10-20% faster than non-colonised plants, even though they are 'giving away' up to 40-50% of their photosynthate to support mycorrhizal networks (photosynthate is the soluble carbon the plant fixed from CO2 and sunlight). One of the reasons for this apparent paradox is that plants colonised by mycorrhizas exhibit higher leaf chlorophyll contents and higher rates of photosynthesis than non-colonised plants (Leake *et al.* 2004). This enables them to fix greater quantities of carbon for transfer to fungal hyphae in the soil.

In exchange for soluble carbon from their host, mycorrhizal fungi supply nutrients such as phosphorus, zinc, calcium, boron, copper and organic nitrogen (Leake *et al.* 2004). It's an amazing symbiotic relationship. Mycorrhizal hyphae have a tubular vacuole system that allows bidirectional flow. That is, dissolved organic carbon from the host plant and nutrients from the soil, or other plants, can move rapidly and simultaneously in opposite directions (Killham 1994, Leake *et al.* 2004).

All groups of mycorrhizal fungi require a living host, but there's more to it than just plants and fungi. A wide range of associative microflora are also involved. For example, colonisation of plant roots by mycorrhizas is enhanced by the presence of certain 'helper' bacteria. There are also active colonies of bacteria on the hyphal tips, producing enzymes which solubilise otherwise unavailable plant nutrients, such as phosphorus.

Mycorrhizas and soil carbon

Glomalin, a long-lived glycoprotein (protein containing plant sugar) is a highly stable form of soil carbon that provides a protective coating for the hyphae of mycorrhizal fungi (Nichols 2008). Networks of fungal hyphae also provide an important first step for the polymerisation of dissolved organic carbon, ultimately leading to the formation of humus, a high molecular weight gel-like substance that holds between four and twenty times its own weight in water (Morris 2004). Humic substances significantly improve aggregation, soil structure, porosity, cation exchange capacity and plant growth. Both glomalin and humus are of significance to the current debate on soil carbon transience, as these stable soil carbon fractions cannot be lost from soil during droughts or fires.

Land management impacts

Increasing the amount of stable carbon stored in agricultural soils via mycorrhizal fungi will require a redesign of many current land management techniques. Factors having negative impacts on mycorrhizas include lack of continuous groundcover in annual systems, single species crops and pastures (monocultures) and application of herbicides, pesticides or fungicides.

Mycorrhizal fungi are also inhibited by the application of large quantities of water-soluble phosphorus and/or nitrogen (Killham 1994) and by the presence of non-mycorrhizal crops (such as canola). Tillage has a less detrimental effect than previously assumed. Recent studies have shown that the use of chemicals is more harmful than moderate soil disturbance. Biology friendly farming practices based on living plant cover throughout the year (eg cover cropping or Pasture Cropping) and the use of biofertilisers such as compost teas, enhance mycorrhizal abundance and diversity and are more beneficial for soil health than chemical farming systems based on intermittently bare soils and minimal disturbance.

Due to their low abundance in annual-based or conventionally managed agricultural landscapes, the important role of mycorrhizal fungi in nutrient acquisition, plant-water dynamics and soil building processes has been largely overlooked

The types of fungi that tend to survive in conventionally managed soils are non-mycorrhizal, that is, they use decaying organic matter such as crop stubbles, dead leaves or dead roots as their energy source rather than being directly connected to living plants. These non-mycorrhizal fungi have relatively small hyphal networks.

Mycorrhizas and water

It is well known that mycorrhizal fungi access and transport nutrients in exchange for the carbon from the host plant (Killham 1994). What is less well known is that in seasonally dry, variable, or unpredictable environments (that is, in most of Australia), mycorrhizal fungi play an extremely important role in plant-water dynamics. The hyphal tips are hydrophilic - both the end in the plant and the end in the soil - enabling both water and nutrients to diffuse from one end to the other along a moisture gradient (Allen 2007).

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 probably of greater importance than cytoplasmic flow (Allen 2007). Further, mycorrhizal fungi can increase drought resistance by stimulating an increase in the number and depth of plant roots.

Perennial grasses and mycorrhizas

Higher densities of mycorrhizal hyphae are found in healthy perennial grasslands than in any other plant community. It has been estimated that the hyphae in the top 10cm of as little as four square metres ($4m^2$) of perennial grassland, if joined end to end, would stretch all the way around the equator (Leake *et al.* 2004).

Broadacre cropping could benefit enormously from widely spaced rows or clumps of long-lived perennial grasses and/or mycorrhizal fodder shrubs. As yet we do not know the required critical mass to improve soil ecosystem function, but it might only need to be 5-10% perennial cover. In diverse plant communities, mycorrhiza compatible plants join common mycelial networks called guilds (Leake *et al.* 2004). These networks connect plants with each other, enabling exchange of nutrients and water (Killham 1994). This may help explain why mixed plant communities often perform better than monocultures.

In addition to the resilience conferred by mycorrhizal guilds, the benefit of permanent mycelial networks in terms of aggregate stability, porosity, improved soil water holding capacity, reduced erosivity and enhanced nutrient availability in soils are immense.

Soil benefits in many ways from the presence of living plants year-round, due to reduced erosion, buffered temperatures, enhanced infiltration and markedly improved habitat for soil biota. Significantly, it is the photosynthetic capacity of living plants (rather than the amount of dead biomass added to soil) that is the main driver for soil carbon accumulation.

Management techniques that improve the vigour of groundcover, foster mycorrhizal colonisation, increase glomalin production and enhance the humification process, will contribute to long-term carbon storage, improved soil function and markedly increased resilience to climatic variability.

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APPENDIX I: Relationship between soil carbon and soil water

Water storage in soil depends on many factors, including rainfall, soil depth, soil texture and the clay minerals present. We cannot control rainfall or soil type. But we certainly CAN influence the capacity of the soil to store water.

Changes to groundcover management can have highly significant effects on levels of soil organic carbon, influencing soil surface condition, soil structure, porosity, aeration, bulk density, infiltration rates, water storage potential and the amount of plant available water. An improvement in any of these factors increases the effectiveness of the rain that falls, enhancing productivity as well as reducing rates of erosion, dispersion, waterlogging and dryland salinity.

Many soils in the early period of European settlement in Australia were described as soft, spongy and absorbent, due to their high organic matter levels. There are several reasons for the better soil water holding capacity of high carbon soils

i) Soil organic matter has, of itself, a sponge-like quality and high water holding capacity. Hence the more organic matter, the more water that soil can hold.

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

From this we can calculate how water storage in the top 30 cm of soil is influenced by changes in the level of soil organic carbon. The majority of Australian topsoils have bulk densities in the range 1.2 to 1.8 g/cm^3. Data shown in Table 1 assumes an average soil bulk density of 1.4 g/cm^3.

Table 1. Relationship between levels of soil organic carbon (OC) in the 0-30 cm soil profile and additional soil water holding capacity. Average soil bulk density 1.4 g/cm^3

Change in OC concentration	Change in OC stock (kg/m^2)	Extra water (litres/m^2)	Extra water (litres/ha)	CO_2 sequestered (t/ha)
1%	4.2	16.8	168,000	154
2%	8.4	33.6	336,000	308
3%	12.6	50.4	504,000	462
4%	16.8	67.2	672,000	616

The data in Table 1 show 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. That’s 168,000 litres, or almost 20,000 **extra** buckets of water that could be stored per hectare, in **addition** to the water-holding capacity of the soil itself.

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

As soil carbon levels fall, evaporation rates increase, degraded soils continue to lose their capacity to hold water and rivers lose their lifelines - the fresh-water aquifers that feed them.

ii) In seasonally dry environments, perennial plants contribute to soil water balance via the processes of hydraulic lift and hydraulic redistribution (Allen 2007). These processes bring moisture to the root-zone to support microbial biomass and maintain plant nutrition. Neither hydraulic lift nor hydraulic redistribution occur under annual crops or pastures.

iii) The photosynthetic activity of plants provides a steady supply of energy to soil microbial communities. Microorganisms of various kinds produce an array of sticky secretions and thread-like filaments that bind mineral particles together into aggregates, improving soil structure and increasing the amount of water that soil can hold. Microbial secretions also help strengthen soil aggregates so they don't collapse when wet.

Improved soil structure assists with the infiltration of rainfall, reducing the rates of erosion. Water moving across the top of the ground collects soil and organic matter. These valuable components are depleted from farmland and deposited as unwanted sediment in waterways.

Increased infiltration is the key to rehydrating the landscape, enhancing plant growth and improving water quality, conferring multiple production benefits to landholders. When water passes through plant roots and healthy soil it is biologically filtered.

High infiltration rates in the upper parts of catchments replenish transmissive fresh water aquifers and foster perennial, moderated baseflow to streams. If groundcover is poor and soil water holding capacity is low, rapid run-off leads to boom-bust streamflow, resulting in water-logging and frequent flooding in lower landscape positions in wet years and inadequate streamflow in dry years.

Soil water balance

Re-balancing the soil water equation and re-balancing the soil carbon equation have many factors in common. Both processes require summer-green groundcover for sequestration of atmospheric carbon (Appendix D) and maintenance of mycorrhizal networks (Appendix H). Charman and Roper (2000), note that in order to increase soil organic matter levels and develop optimum physical and biological conditions, farmed soil should be managed in a similar way to a perennial pasture.

Factors that **reduce soil organic carbon levels** and disrupt **soil water balance** include

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

Most conventional agricultural practices include one or more - or all - of the above. 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 (Table 1).**

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

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

The carbon cycle and water cycle are intrinsically linked

High soil carbon = improved water infiltration = recharge of transmissive aquifers = perennial base flow to rivers and streams.

Low soil carbon = high evaporation = loss of perennial streamflow

The longer we delay undertaking changes to land management, the more soil (and soil carbon and soil water) will be lost, exposing an increasingly fragile agricultural sector to escalating production risks and vulnerability to climatic extremes.

Fig.1. The well grassed area on the left has good infiltration compared to the over-grazed area on the right, which has lost soil carbon and soil water-holding capacity. Rainfall that cannot infiltrate simply sits on top of the ground and evaporates. (Photo Patrick Francis).

Carbon dioxide emissions

In addition to water losses from the landscape, a 3% reduction (by weight) in soil organic carbon in the 0-30 cm soil profile represents 462 t/ha extra carbon dioxide (CO_2) emitted to the atmosphere, contributing to increased levels of greenhouse gases. That is, **462,000 tonnes of CO_2 emissions for every thousand hectares of land.**

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APPENDIX J: Soil carbon, human health and a 'Soil Integrity Index'

The key purpose of farming is - or should be - to produce nutritious food that benefits the health and well-being of the population. In reality, the farming sector sits at the centre of a complex, capital intensive supply chain focussed largely on production. Decisions are based on the cost of inputs and the anticipated value of outputs. Rarely is the nutritional value of the product considered. The health of consumers has tended be viewed as a technical problem that can be fixed with an endless variety of pharmacological magic bullets - accompanied by seemingly limitless unpleasant side effects.

Interestingly, when people are asked which factors are of greatest importance to them personally, good health nearly always tops the list. **Contrary to popular belief, good health is not determined by the quality of our medical system**. Rather, it is closely linked to the nutrient content of food - which in turn is linked to the ecological health and organic carbon content of the soil in which food is grown.

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.

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 carbon levels, in turn, are linked to the quality of groundcover.

Routine premature deaths by 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, was found to be copper 76%, calcium 46%, iron 27%, magnesium 24% and potassium 16%.

Vitamin and mineral deficiencies in food indicate that the symbiotic relationship between plants and soil microbes, by which minerals and carbon are exchanged, has been disrupted. The soil conditions required for flourishing microbial populations are diminished by the use of herbicides, fungicides, pesticides and high rates of phosphatic and nitrogenous fertilisers. Conversely, conditions for biological activity are enhanced by exudates from plant roots and the application of biofertilisers such as worm leachate, compost teas and other microbial inoculants.

Tim Wiley, WA Department of Agriculture and Food, found availabilities of important plant nutrients tripled in the soil beneath perennial grasses (Wiley 2009). These data are shown in Table 1, Appendix F.

Improvements in plant nutritional status (and a raft of other productivity and environmental benefits) formed the basis for the recommendation by Portugal's Professor Tiago Domingos, Coordinator of Project Extensity and Terraprima project leader, that perennial grasses be used as understorey species in horticultural enterprises as well as in extensive livestock production (Watson 2010).

Indeed, it is in the personal interest of each and everyone to ensure that efforts be taken to improve levels of carbon sequestration in soil. Apart from the obvious benefits of increased soil carbon for soil fertility and agricultural productivity, the relationship between soil carbon and soil nutrients has important implications for human health.

As levels of soil carbon decline, levels of available plant nutrients decline, the mineral density of food falls and human health suffers. 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 diseases that are mostly nutrition related, that is, they 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 dependant on active soil sequestration.

Food labelling and a 'Soil Integrity Index'

People's 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) soil carbon content
ii) soil water holding capacity and
iii) level of microbial diversity

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, the city-based population could use food choices to improve not only their own health, but also the health and resilience of agricultural soils, thereby actively participating and supporting climate friendly farming.

The establishment of a Soil Stewardship Scheme, as outlined in Appendix K, would provide an ideal opportunity for the development of a 'soil integrity' accreditation system for soils and an accompanying prototype for a food labelling system.

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Appendix K: Soil Stewardship Scheme

The Victorian Government could fast-track the adoption of innovative farming technologies that improve levels of soil carbon, confer resilience in a variable climate, increase farm productivity and improve the international competitiveness of the agricultural sector, via the underwriting of a Soil Stewardship Scheme.

The desired outcome of the Soil Stewardship Scheme would be the restoration of fundamentally important ecosystem processes, particularly the carbon, water and nutrient cycles, at local, regional and catchment scales.

The most effective way to generate on-ground change is to actively engage landholders in participatory approaches to innovation and extension. The vision is for a wide range of people and organisations to be involved in a decentralised network of 10 regional collectives supporting a combined total of 100 Community Research Farms. The role of the collectives would be to coordinate educational materials and workshops and administer funds to assist landholders to restore carbon-rich topsoils via the reinstatement of biodiverse perennial summer-green groundcover. Regional collectives would also be responsible for monitoring and evaluation programs to determine the effectiveness of the soil building techniques.

Funds provided by the Victorian Government would be used to enable landholders on Community Research Farms to convert a ‘designated sequestration area’ of 10 hectares, currently used for dryland annual cropping and/or livestock grazing on annual pasture, to perennial summer-green groundcover, preferably enhancing natural recruitment using the technique of Pasture Cropping (Cluff and Seis, 1997).

The ‘designated sequestration areas’ on Community Research Farms would serve as demonstration sites to provide on-ground proof of

i) carbon sequestration
ii) active soil-building
iii) improved soil water-holding capacity
iv) biodiversity enhancement
v) reduced weed burdens
vi) resilient agricultural production
vii) improvements to landscape function and
viii) aesthetic benefits of yearlong green farming techniques

Community Research Farms would provide the basis for increased networking and support among landholders across Victoria, giving a wide range of people the opportunity to share knowledge and experience gained with soil restoration technologies and the confidence to try new options. They would also serve as design and innovation templates for expansion to other properties - regionally, nationally and internationally.

As a result of the measured and publicised benefits of the stewardship scheme, it is anticipated that regenerative farming techniques would be widely adopted throughout the agricultural community, hence not requiring further government funding other than the initial five year allocation.

The proposed Soil Stewardship Scheme is clearly defined, targeted, low-cost, achievable, outcome based, incentive driven and immediately available for implementation.

Soil sequestration benefits

As outlined in Appendix C, the restoration of perennial groundcover has the potential to increase soil carbon levels in Victorian agricultural soils by around 1% in low rainfall areas and up to 3% in higher rainfall areas. An increase of 1% (by weight) in the level of soil carbon in the 0-30cm soil profile equates to sequestration of 154 tCO_2/ha if an average bulk density of 1.4 g/cm^3 is assumed,

Victorian emissions are currently around 123 million tonnes of CO2. These emissions could be sequestered in 800,000 ha of regeneratively managed farmland in which soil carbon levels were increased by 1%.

Soil carbon increases could be financially rewarded by incentive payments through a project-based soil carbon offsets scheme involving the voluntary carbon market (Appendix L).

The future landscape

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

The soil sink would be permanent if the land-use change was permanent. There are a multitude of powerful reasons for change, not the least of which are the aesthetic and productivity benefits associated with the transformation of the current dehydrated summer-brown Victorian landscape to a rehydrated summer-green landscape.

An increase in the number of carbon-wise farmers would facilitate healthy soils, revitalised catchments and wealthy communities far into the future - well beyond the lifetimes of those involved in the establishment of this project.

Implementation

The proposed Soil Stewardship Scheme would be implemented by existing regional collectives such as Landcare networks, farming organisations and Natural Resource and Catchment Authorities, with guidance provided by Dr Christine Jones, founder of the Australian Soil Carbon Accreditation Scheme (www.amazingcarbon.com) and coordinator of the prestigious Green Agriculture Innovation Awards.

Regional collectives would be responsible for project coordination, the organisation and running of workshops on regenerative land management techniques and the administration of financial and technical assistance to enable landholders to convert designated areas from ephemeral summer-brown groundcover to perennial summer-green groundcover. This would include the purchase of seed, biology-friendly fertilisers and contract planting.

In order to be considered for inclusion in the Soil Stewardship Scheme a regional collective would need to demonstrate the ability to effectively oversee a minimum of 10 Community Research Farms.

Regional collectives would be responsible for annual measurement and reporting of soil carbon levels, soil nutrient status and soil moisture-holding capacity on Community Research Farm demonstration sites.

It is proposed that regional collectives receive funding in the order or $200,000 per annum from the Victorian Government to enable them to undertake these tasks.

Project costings

Costings are based on the assumption that two regional collectives (20 Community Research Farms) be funded in 2010, with another three (30 Community Research Farms) added in 2011 and a further five regional collectives (50 Community Research Farms) brought into the scheme in 2012.

The ten regional collectives would support a minimum of 100 Community Research Farms across Victoria.

It is proposed that the Soil Stewardship Scheme operate for 5 years.

Estimated costs

2010: 2 x $200,00 = $400,000
2011: 5 x $200,000 = $1,000,000
2012: 10 x $200,000 = $2,000,000
2013: 10 x $200,000 = $2,000,000
2014: 10 x $200,000 = $2,000,000

Total: $7,400,000 ($7.4 million)

ii) Cost of doing nothing

The number of farmers has fallen 30 per cent in the last 20 years, with more than 10,000 farming families leaving the agricultural sector (Australia wide) in the last five years. 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.

The costs of **not** assisting farmers with the implementation of regenerative land management technologies are immense. They include rising input costs for fuel and fertiliser to prop up failing land management regimes, ongoing agricultural emissions, continued drying out of soils due to low carbon levels, reduced resilience of agricultural enterprises to climatic extremes and the impact of deteriorating soils on food quality and human health.

The long-term cost of inaction is inestimable.

Professor Stuart Hill (Hill 2002) makes this point abundantly clear:-

> "If we all postpone taking such action, it is certain that the quality of life of future generations will progressively be degraded as we continue to lose our soils, habitats and other species with which we share this amazing planet."

Recent soil carbon workshops in Victoria

Dr Jones is currently working with a wide cross-section of Australian landholders in all states to implement yearlong green, highly productive approaches to land management that confer resilience in a warming, drying environment, while reversing the farm sector's carbon and nitrogen footprints.

Dr Jones has been actively involved in conferences, workshops and field days on soil carbon in Victoria since early 2006. The majority of events have been attracted 100-200 landholders, with venues often filled to capacity. Recent workshops with the Victorian farming community have included ….

Benalla 26 February 2009. Federation of Biological Farmers. Convention or innovation? “Victorian landscapes, past, present and future”
Corryong 21 April 2009. Upper Murray Landcare Network. “Building soil carbon”
Bairnsdale 20 July 2009. Greening Australia East Gippsland Revegetation and Grassland Project. “Adapting farming to climate variability”
Tambo Crossing 21 July 2009. Evergraze project. Soil carbon field day
Geelong 30-31 July 2009. Team Te Mania & Elders. “Face of future farming workshop”
Yea 13 October 2009. Paringa Livestock seminar and paddock walk. “Sequestering carbon in agricultural soils”
Thoona 10-11 November 2009. Goulburn Broken Catchment Landcare Network (Gecko CLaN). . “Improving biodiversity and regenerating soils” workshop and field visits to participating farms.

Copies of workshop fliers and notes are available on request.

Catchment Management Authorities and community groups including several Landcare networks and the Sustainable Agriculture and Communities Alliance have engaged Dr Jones to run further workshops in Victoria during 2010.

Recent publicity

ABC Landline. ‘Ground Control’ (story on Australian Soil Carbon Accreditation Scheme). Repeated 20 December 2009 on ‘The Best of Landline for 2009’ http://www.abc.net.au/landline/content/2008/s2490568.htm

ABC Late Night Live. How much carbon can we store in soil? 4 February 2010 http://www.abc.net.au/rn/latenightlive/stories/2010/2809236.htm

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APPENDIX L: Project-based soil carbon offsets

Carbon is the master nutrient for soil, improving its physical, chemical and biological health. The sequestration of atmospheric carbon simultaneously filters the air and nourishes soil life, reducing atmospheric CO_2 while restoring productivity to the land. The establishment of an audited soil carbon offsets scheme to support the benefits of soil sequestration would therefore be in the wider public interest.

It is proposed that an incentive payment of $5 per tonne per annum for CO_2 sequestered in soils in the designated 10 ha sites on 100 Community Research Farms be arranged through the voluntary carbon market as a value-adding extension to the Soil Stewardship Scheme. Soil carbon incentive payments (SCIPs) could be capped at 5 years, setting a maximum of $25 per tonne for CO_2 sequestered over the life of the project.

Compliance with the National Carbon Offset Standard (Department of Climate Change 2009) would provide confidence to businesses wishing to participate in the voluntary market, enabling them to assist in a meaningful way with the restoration of soil health and the revitalisation of rural communities.

The availability of soil carbon payments would provide financial incentive for landholders to join the network of Community Research Farms. As an integral part of the Soil Stewardship Scheme, soil carbon levels would be baselined in the first year and determined annually thereafter, providing a valuable database for rates of soil carbon sequestration under regenerative agricultural regimes.

These data would enable on-ground results and real-time assessment of the implications for a broader, project-based soil carbon offsets scheme operating under the Federal Government's proposed CPRS. A national soil-based sequestration scheme could play a vital role in emissions trading in the future. It would also reward landholders for the provision of environmental services, through carbon markets.

Irrespective of whether temperatures increase, decrease or stay the same, soil carbon restoration utilising funds derived from both the voluntary market and the CPRS would build real wealth in rural communities (based on improvements to natural capital) and improve the quality and security of food and water.

Value-adding opportunities are also envisaged. Businesses and organisations offsetting their emissions in agricultural soils could use the 'Carbon Neutral' logo provided as part of the National Carbon Offset Standard (Department of Climate Change 2009). Farm produce could be labelled as 'Carbon Credited' or 'Climate Friendly' where appropriate and marketed to a rapidly expanding environmentally-conscious market.

Portuguese soil carbon offsets scheme

In July 2009, the Portuguese government introduced a soil carbon offsets scheme based on dryland pasture improvement. The A$13.8 million Portuguese initiative complies 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 health, 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, believes sequestration of CO_2 in perennial grasslands will be part of the emission mitigation landscape of the future (Watson 2010).

Professor Domingos notes that the area of agricultural land in Portugal amenable to soil carbon offsets via the establishment of perennial pasture could collectively sequester more than the current Portuguese national emissions deficit under existing Kyoto arrangements (Watson 2010).

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