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The Hon. John Pandazopoulos MP
Chair
Environment and Natural Resources Committee
Parliament of Victoria
Spring St
EAST MELBOURNE VIC 3002

Inquiry into soil carbon sequestration in Victoria
Submission no. 34

Dear John

ENRC SOILS INQUIRY

Late last year the Environment and Natural Resources Committee wrote to the Departments of Sustainability and Environment and Primary Industries seeking their views on the issue of carbon sequestration in soil.

Please find attached the Victorian Government's submission to the committee on this issue.

I trust the committee will find the government's submission useful in its further deliberations.

Yours sincerely

GAVIN JENNINGS MLC
Minister for Environment and Climate Change

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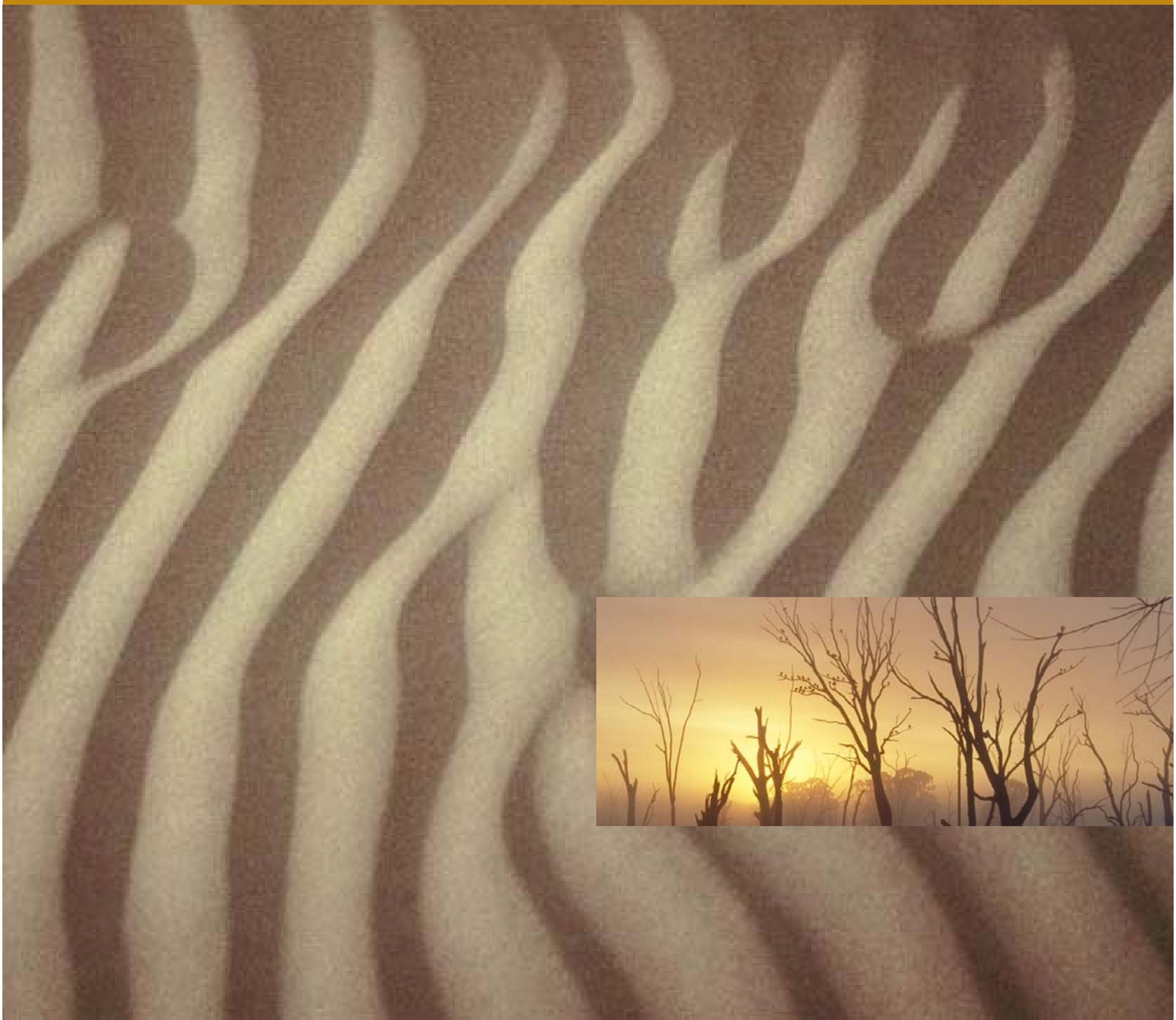
ENRC Inquiry

SOIL SEQUESTRATION IN VICTORIA

Victorian Government Submission



May 2010

Victoria
The Place To Be

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Introduction

Climate change is raising very complex policy issues. As Professor Ross Garnaut stated in his 2008 report to the Australian Governments ‘It is harder than any other issue of high importance that has come before our polity in living memory.’

Soil carbon sequestration is often put forward as a mechanism to help reduce or mitigate greenhouse gas emissions in the atmosphere. Some see the sequestration of carbon in agricultural soils as a substantial source of future revenue. However, increasing soil carbon stocks may also result in unwanted adverse impacts.

The behaviour of soils is complex, however, and building additional stocks of carbon in soils on a permanent basis can be difficult to achieve and measure, and is affected by many variables. Evidence and analysis is needed to complement the enthusiasm and potential for soil carbon sequestration.

The Victorian Government welcomes this inquiry as an opportunity to explore this complex, yet potentially rewarding area of activity and to do so in a way that draws on available evidence and engages the community.

This submission includes information and analysis on each of the Committee’s terms of reference. The aim of the submission is to highlight what is and what is not known about soil carbon sequestration, to present a framework to help identify the potential role of the Victorian Government in this area and to stimulate and inform further discussion.

Executive Summary

Human-induced (anthropogenic) climate change in the 21st century is very likely according to the 4th IPCC report (2007). During the 1990's, primarily as a consequence of the Kyoto Protocol, the global focus was on reducing human-induced greenhouse gas emissions. However, the growing evidence of significant human-induced climate change impacts over the 21st century has seen an increased emphasis on managed adaptation.

The enhancement of natural carbon sinks is considered worldwide as a beneficial method of reducing the greenhouse effect. The management of terrestrial landscapes for increased carbon storage could assist in offsetting greenhouse gas emissions, as well restoring degraded landscapes across Australia.

Carbon is stored and released as CO_2 through a complex series of bio- and geo-physical processes globally. This global "carbon cycle" is dynamic but balanced: losses of carbon in one part of the global cycle are balanced by increases of carbon (or CO_2 emissions) in another.

The quantity and form of carbon stored within soil is dependent on soil type, climate, vegetation, and land management practices. Forested regions generally contain more soil carbon than agricultural land, and the act of clearing native vegetation usually results in a net loss of soil carbon. While there is potential for carbon sequestration in both land-use types, land use change represents the single greatest driver of soil carbon change in Victoria.

Increased carbon sequestration in soil can only result from either reduced outputs, or increased inputs of carbon. However, determining the amount of carbon stored is limited by biophysical and measurement constraints. Any increase in carbon sequestration and resultant environmental benefits must be weighed against the potential for adverse impacts. For example, the link between the soil carbon cycle and key nutrients, such as nitrogen, are key determinants of agricultural system productivity. Therefore, *the net change in* greenhouse gas emissions should be assessed for any land management practice changes.

Using the National Carbon Accounting System (NCAS), the Victorian Government is modelling the amount of carbon that is stored in soils. This baseline can be used to estimate impacts of future land-use and land-use change.

Key Messages

- Soil carbon sequestration is highly dynamic balance between inputs and rates of loss, which varies with soil characteristics, climate and land management practices. It is difficult to permanently sequester carbon and soil carbon is easily lost. Further, there are limits to the amount of carbon soils can sequester in agriculture systems.
- There are costs and challenges associated with sequestering carbon into soil including:
  - environmental costs such as emissions of other greenhouse gases,
  - costs associated with changed land management practices,
  - the measurement of soil carbon, and
  - the potential for future liabilities.
- There are also a number of possible agronomic and environmental benefits in addition to the removal of carbon from the atmosphere, including:
  - enhanced nutrient storage and supply, and soil productivity;
  - improved biodiversity and landscape health;
  - greater water retention and improved water quality;
  - erosion control;
  - additional food and habitat for soil micro-organisms;
- Information on the size or significance and longevity of these additional benefits is currently very limited.
- The form of carbon added to soil influences the potential for benefit and harm, for both agricultural production and environmental outcomes, as do climate conditions.
- Consistent, rigorous and repeatable protocols are used when selecting soil samples (for carbon measurement) to limit variation due to external factors, including seasonal variations, and these sampling techniques are subject to continuous improvement. However, consideration must still be given to the inherent biological variability of soils by temporal, spatial and managerial dimensions.
- Using the National Carbon Accounting Toolbox (NCAT) FullCAM model, an indicative estimate of soil carbon stocks across Victoria's publicly managed land indicates storage of up to 500 million tonnes of carbon. There is no equivalent estimate for private land. NCAT is likely to be specifically linked to any proposed ETS.
- Victoria's Catchment and Land Protection Act (1994) provides a useful framework for work on soil health and soil carbon sequestration.
- The Victorian Government is investing in and researching soil carbon sequestration on public and private land. For example, the Victorian Government's Future Farming strategy is supporting research investigating soil carbon sequestration and its measurement on agricultural land. A soil health policy framework is also being developed as part of the Future Farming strategy.
- On 24 November 2009 the Commonwealth Government published the final National Carbon Offset Standard (NCOS). The NCOS identifies reduced emissions from agricultural soils and soil carbon sequestration as eligible activities for the generation of domestic voluntary offsets.
- The Victorian Government released its Land and Biodiversity Securing our National Future Paper in December 2009. The White Paper sets out the Government's agenda for land, water and biodiversity at a time of climate change.
- A better understanding of complex, interactive soil and related systems across whole farm, forestry, and natural systems over extended periods, and improved measurement systems are required to enable land managers to operate more efficiently in commodity, carbon and other ecosystem markets. It will also be important to understand any unintended adverse impacts of sequestering soil carbon. This information will also help guide policy makers in designing effective policy measures.

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An introduction to soil carbon sequestration

Soil carbon sequestration

Soil carbon sequestration involves removing CO_2 from the atmosphere through biological processes and storing in the soil

Soil carbon sequestration is the process by which organic carbon stored in the soil is increased, thereby contributing to the reduction of CO_2 in the atmosphere via the carbon cycle (Figure 1). Soil systems, including carbon are intrinsically linked to the above-ground environment, and it is important when referring to carbon to consider above- and below-ground environments as a continuum.

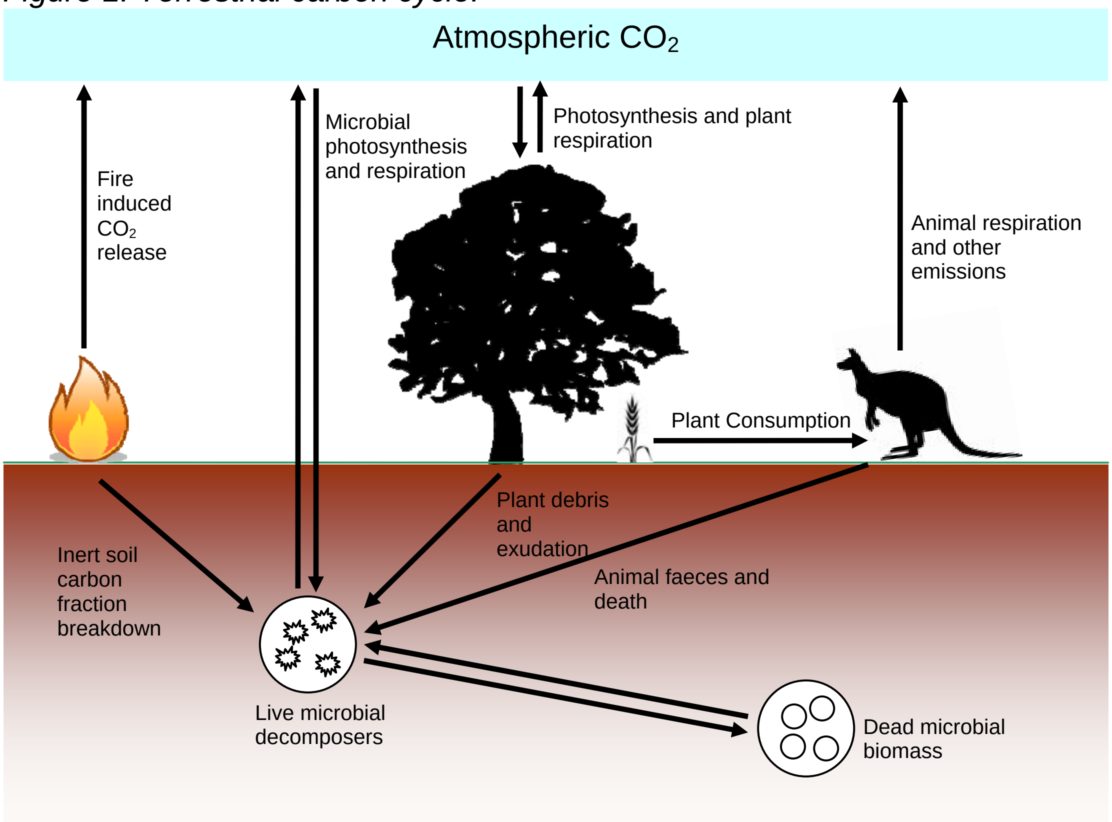
The carbon content of soil is a dynamic balance of multiple processes

At any point in time, the organic carbon content of a soil is a balance between the rate of input from living organic matter (plants, animals, microbes) and the rate of loss (through decomposition and respiration). Both the amount of input and the rate of loss are affected by:

- soil characteristics, e.g. texture, clay content and type,
- climate such as rainfall and temperature, and
- land management practices, e.g. crop type, tillage, stubble retention, grazing etc.

The rate at which carbon can be sequestered in soil is therefore dependent upon a combination of these factors, and the net extent to which the rate of input can exceed the rate of decomposition.

Figure 1. Terrestrial carbon cycle.



Terms of reference

(a) possible benefits to the agricultural industry

Key Messages

- While there are costs and issues associated with soil sequestration, there are a number of possible agronomic benefits to farmers, including: nutrient storage and supply, soil water, erosion control, and food and habitat for soil micro-organisms.
- In a future low carbon Australian economy farmers could potentially gain a financial benefit for increasing their rates of sequestered soil carbon. However, they would also face financial costs if their measured amount of soil carbon subsequently declined in any future accounting period.
- Initial research by the Victorian Government suggests that the predominant soil types in Victoria could potentially sequester more carbon. However, this theoretical research is subject to a number of very important caveats and needs to be verified experimentally.
- The Victorian Government, in conjunction with agricultural industries and other agencies in Australia through the Climate Change Research Strategy for Primary Industries (CCRSPI), is actively undertaking research on soil carbon sequestration to understand the possible benefits to agricultural industries in Victoria.

There are a number of possible benefits to the agricultural industry which are presented in this section. These include:

- agronomic benefits;
- climate change policy benefits.

The costs and other issues associated with soil sequestration will be addressed in the subsequent sections.

Agronomic benefits

Soil carbon sequestration directly links to soil health

By definition, soil sequestration results in increased levels of soil organic carbon and soil organic matter. It is widely recognised that increased soil organic matter is of benefit to agriculture because of its positive impact on the soil and in turn on sustainable agricultural production. Practices and policies that encourage maintaining and improving soil carbon sequestration are generally associated with improved soil health.

Some of these benefits include:

- *Nutrient storage and supply* – in simple terms, soil organic matter provides a bank through which nutrients (nitrogen, phosphorus, and sulphur) are stored and supplied to the growing plant;
- *Soil water* – soil organic matter helps to improve soil structure and increase soil aeration, allowing water and air to move more easily through the soil profile, whilst also increasing the water holding capacity of the soil. This is of particular importance in times of reduced rainfall;
- *Erosion control* – soil organic matter stabilises the surface soil, binding soil particles into aggregates that are more resistant to erosion;
- *Cost savings* - moving to a minimum or no till system is also likely to result in reductions in fuel costs as these systems employ significantly lower cultivation;
- *Food and habitat for soil micro-organisms* – the benefits of a healthy, diverse and active soil fauna and flora population are well recognised. Soil organic matter provides both food and habitat for earthworms, insects, bacteria, fungi and a range of other living organisms, all of which contribute to a diverse microbial activity. This in turn generally leads to greater biological control of plant diseases and pests.

Carbon credits are not the only benefit of increasing soil carbon

In the absence of any proposed carbon trading scheme or formal recognition of soil sequestration in Australia's policy, there can be benefits to agricultural businesses through the improvement in soil health and potential productivity as a result of enhanced soil organic carbon levels. The Victorian Government has been working with farmers for many years to develop practices that maintain and increase organic carbon in their soil, irrespective of any proposals to promote soil sequestration as a means of reducing greenhouse gas levels in the atmosphere.

But there has been limited research on the benefits to production of increasing soil carbon

Much research on farming systems has been directed at better management of soil such as stubble retention, reduced tillage and weed management. These management changes have generally had positive production impacts, even though the relationship between production and soil organic carbon is not explicit. There are, however, clear relationships between soil organic carbon and other soil properties (for example soil structural stability.)

No studies have been undertaken to show the extent of the net benefits from increasing soil carbon for the purpose of increased production.

Climate change policy benefits

Monetary benefits may be available if soil carbon is recognised in an ETS or voluntary markets

The carbon storage aspects of soil sequestration that might benefit farmers could come from the recognition of increased soil carbon in a formal policy sense (either through an emission trading scheme or some other mechanism, or through a voluntary market). For example, agricultural businesses may benefit from receiving a payment for sequestered carbon or have it recognised as an offset against other greenhouse gas emissions that may arise from their operations.

However, prior to any monetary gain the biophysical potential of soil must be understood

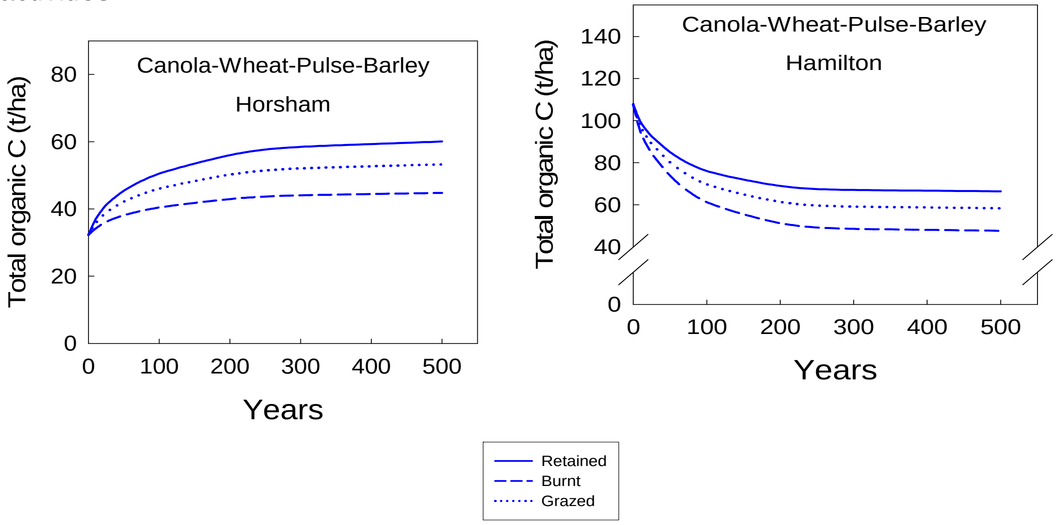
There are many issues with the realisation of these agronomic and policy related benefits, and these are explored in the responses to the subsequent terms of reference of this inquiry. However, the first issue to understand is the biophysical potential of Victoria's soils to sequester carbon, and hence realise these benefits.

a) Benefits from building carbon *in situ*

The Victorian Government has modelled in-situ soil carbon storage in grain growing regions

Victorian Government scientists have used computer simulation models to estimate the potential for soil carbon sequestration in the grain-growing areas of Victoria under a range of standard cropping rotations (see section C on measurement methodologies). These studies can provide an indication of the extent of likely benefits from soil carbon sequestration activities.

*Figure 2: Soil Organic Carbon modelled across a range of management activities***.**



A particular farming practice may cause soil carbon to increase, decrease or stay the same, depending on factors such as climate and initial soil conditions. Figure 2 shows that retention of crop stubble or grazing of the stubble by sheep promoted carbon sequestration at Horsham, but did not prevent decline of soil carbon in Hamilton.

Best result showed between 0.52t and 0.92t C/ha/year

The highest rate of carbon sequestration that could be modelled under a continuous cropping scenario was estimated at 13 tonnes C/ha over a 25 year period (0.52 t C/ha/year). Where pastures were incorporated into the modelled scenarios, under the best possible conditions, the highest rate of estimated sequestration was 23 tonnes C/ha over a 25 year period (0.92 t C/ha/year) (Robertson 2008).

Broadly consistent with Queensland studies

This broadly correlates with modelling by scientists at Queensland University of Technology which suggests that the predominant soil types in Victoria (Sodosols, Chromosols, Dermosols – south west, north central, north east Victoria) can sequester carbon at rates of up to 0.74 t C/ha/year, whilst Vertosols (i.e. Wimmera cracking clays) can potentially sequester carbon at rates of up to 1.48 t C/ha/year over a 25 year period. (Grace 2008)

These results indicate farmers could potentially earn $38/ha at $20/t$CO_2$

Assuming a carbon price of $20 /tonne CO_2e, estimates for a 0.52 tC/ha/year sequestration would imply farmers may earn $38.13 per hectare. Assuming 1.48 t/C/ha/year, this would imply $108.53 per hectare at $20 /tonne CO_2e.

There are some important caveats on these modelled simulations

While these sums can be significant, especially when multiplied over time and area, the above scenarios are subject to a number of very important caveats:

- These are theoretical potential sequestration rates. European studies suggest that the realistic potential may only be 10-50% of the theoretical potential, when dry seasons, poor management and other issues are taken into account;
- The studies assume that the modelled land management practice is constant. However, soil carbon can be lost from the soil even more quickly than it is built up. Even relatively short periods of a less conservative management (e.g. fallow, stubble burning, frequent cultivation) may negate the effects of many years of restorative practices;
- There are maximum limits to how much carbon a soil can store, which depend upon the texture and clay type of the soil. Long term sequestration of soil carbon depends on the carbon being physically and chemically 'protected' from decomposition and there is a limit to how much can be protected. For most soils, we do not know what that maximum limit is. Limited simulation and field-based studies indicate that the rate of increase in soil carbon slows down after the first few decades, as soils approach their upper limits of carbon storage;
- The figures assume that carbon prices, which at this stage only seem likely if soil carbon sequestration were recognised by the formal emissions trading scheme, will be earned by the farmers. A voluntary market could result in a significantly lower price such as that from the Chicago Climate Exchange ($US1 to $US5);
- Currently these lower rates are the most likely outcome for soil carbon, under Australia's National Carbon Offset Standard. However, the price for voluntary soil carbon offsets under a

national standard could reasonably be expected to be higher than the Chicago Climate Exchange.

Victorian Government is examining management with others, options, productivity inputs and carbon sequestration limits

The Victorian Government is working on the management options, the productivity impacts and the potential rates and limits of sequestration in soils so as to better understand the possible benefits to agricultural industries in Victoria. This work is primarily undertaken through its Future Farming Systems Research Division within DPI, in conjunction with agricultural industries and with other agencies in Australia.

b) Externally adding carbon

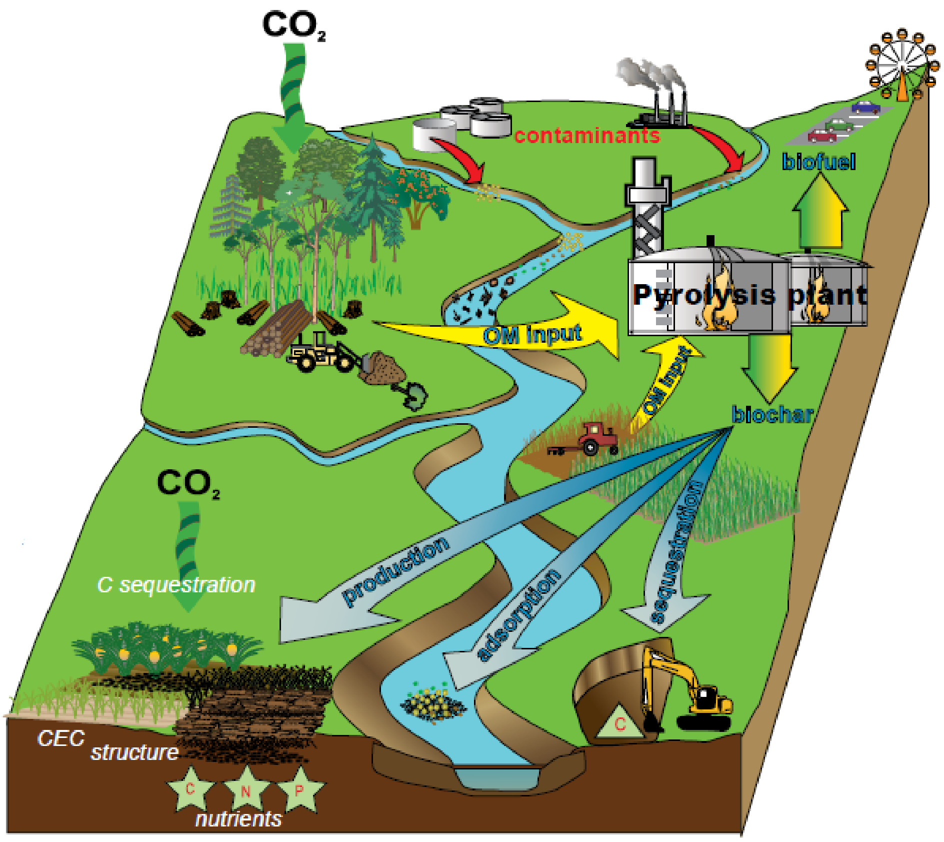
Soil carbon sequestration can also occur by adding carbon from other sources

A potential alternative strategy to sequestering carbon *in situ* through crop and pasture management is to sequester carbon using external sources of carbon, such as adding manure, compost or other organic materials such as biochar.

Adding biochar from the pyrolysis of organic material to soils has the potential to provide net sequestering benefits

Biochar is a type of charcoal by-product that results from pyrolysis of natural organic materials. The production of biochar via pyrolysis yields bioenergy as well as other products. (Figure 3)

Figure 3: Production and application of biochar



Source CSIRO Biochar factsheet

Biochar is potentially stable and may have benefits to soil health

The composition of biochar, and hence its properties, varies widely depending on the material being used and the conditions of the pyrolysis. Biochars are more stable than uncharred organic material and may have potential for storing carbon over a long period of time (potentially up to thousands of years (CSIRO 2008).

Biochar and other additives may provide significant benefits for agriculture, including:

- net carbon sequestration (see below)
- increased crop yield
- nutrient retention in soils
- nutrient availability and efficient use
- water retention
- microbial growth /activity (biodiversity)

Net carbon sequestration though biochar can occur via:

1. The conversion of organic matter (such as plant matter or manure), which contain carbon, to biochar (which is a stable form of carbon) that is stored on a long-term basis (either in soils or underground)
2. The application of biochar to farming land which can then stimulate the build-up of organic carbon in the soils (ie encouraging in-situ soil carbon).

However, there is significant uncertainty around the costs and benefits of biochar

Recognising that there are costs involved in the transport and distribution of external sources of carbon, a full life-cycle analysis is required for any proposed technique to determine whether there is a net gain in carbon sequestered from the atmosphere. Hence, there is significant uncertainty around the size of the benefits and possible perverse outcomes associated with biochar being added to soils.

The potential benefits and costs of biochar are currently being researched by a number of agencies in Australia (including NSW Department of Industry and Investment, highlighted in Box 1), but no credible studies have yet been completed. The Victorian Government, through its agencies and departments, is closely connected to this research.

Box 1 Biochar projects undertaken by NSW

NSW Department of Industry and Investment has a number of current projects researching aspects of biochar (see www. http://www.dpi.nsw.gov.au/research/topics/biochar).

Project titles include

- Land management to increase soil carbon sequestration in NSW
- Assessment of biochar for agronomic benefits, improved fertiliser use efficiency, greenhouse gas abatement, and reduced off-site migration of chemicals.
- Soil carbon sequestration and rehabilitation: Landholders develop, implement and assess biochar
- Benefits of paper mill biochar (Agrichar™)
- Assessment of biochar in sugarcane cropping systems
- Characterisation of biochar by analytical Py-GC-MS
- Reduction in N_2O emissions from soils amended with biochar
- Nitrogen dynamics of biochar in soils

Key results from these research programs to date include:

- Control plot yields of radish dry matter increased over the control by 42% at 10 t/ha and 96% at 50 t/ha biochar application using poultry litter biochars
- Biochar produced from greenwaste by pyrolysis on the yield of radish produced no increase in yield in the absence of nitrogen fertiliser, at rates up to 100t/ha. However, application of nitrogen fertiliser increased yields by up to 266% at 100 t/ha biochar application rates.

The Victorian Government will continue to liaise with the NSW Department of Industry and Investment over future results.

Terms of Reference

(b): possible environmental benefits

Key Messages

- There are a number of possible environmental benefits, such as, erosion control, biodiversity, water quality, landscape health, and productivity
- Using the National Carbon Accounting Toolbox (NCAT) FullCAM model, an indicative estimate of soil carbon stocks across Victoria's publicly managed land indicates storage of up to 500 million tonnes of carbon.
- The Victorian government is actively working with the Federal Department of Climate Change (DCC) to continue development of NCAT;
- Rates of increase of soil carbon on public land are primarily associated with forested land subjected to disturbance, with the rate of increase proportionally related to the time since disturbance (fire/harvesting). Forest that is long undisturbed is largely in equilibrium, with gains largely equal to losses.
- Through research linkages, the Commonwealth and State Governments, various agencies, and Universities, are actively working on research priorities, management options, and a monitoring and reporting framework.

Environmental benefits of carbon sequestration

The key proposed benefits of soil carbon sequestration is reduced atmospheric CO_2

Soil carbon constitutes more than 50 % of terrestrial carbon and is an important attribute of soil and landscape health. The main direct environmental benefit of increasing soil carbon sequestration is the reduction of atmospheric CO_2 concentration. This in turn could reduce the extent of expected climatic change due to human activity. To increase the amount of carbon stored in soils, carbon fixation through photosynthesis needs to be enhanced and /or net soil carbon loss reduced. As noted earlier, the health of the above-ground environment is linked to the health of the below-ground environment and soil carbon is one constituent of more general soil health.

Significant additional environmental benefits can also be gained

It is widely recognised that increased soil organic matter has significant environmental benefits beyond that of reducing CO_2 in the atmosphere. Many of these benefits overlap with the agronomic benefits outlined in the previous section. These include improving physical, chemical and biological properties and processes both within the soil and in "flow on" effects to the wider landscape.

Some of these benefits include:

- *Erosion control* – Soil organic matter reduces the potential for soil erosion by improving soil structure and stability;
- *Environmental buffering* – Soil organic matter increases the buffering potential of soil, reducing water body eutrophication (nutrient overloading in waterways) by enhanced retention of nitrogen and phosphorus, and potentially the ability to retain other pollutants and contaminants;
- *Hydrological cycle* – Soil organic matter directly provides improvements in hydrological dynamics and water quality (infiltration, retention, and filtering);
- *Biological diversity* – Soil organic matter directly provides a habitat and substrate for soil (micro-) organisms, which underpin many biogeochemical processes and general ecosystem resilience (the ability for processes to continue after disturbance and to recover);
- *Nutrient storage and supply* – Soil organic matter contains some of the trace elements and nutrients (such as organic acids, nitrogen, sulphur, and phosphorus) that sustains microbial communities and allow plant growth. The link between soil organic matter and nutrient availability is particularly strong in natural systems, where external additions of nutrients are uncommon or where fire is a major driver of nutrient release.

The Environmental benefits of soil carbon sequestration can be significant but are uncertain and rarely valued.

These broad environmental benefits of soil carbon sequestration may be as significant as any direct benefit of removing carbon from the atmosphere. Indeed, research undertaken by the Victorian Government suggests environmental benefits of increased soil carbon sequestration are significant.

Yet there remains much uncertainty about carbon fluxes and the size of the benefits additional carbon in the soils may bring. The Victorian Government, in partnership with Catchment Management Authorities (CMAs) and research institutions is actively working to assess and increase knowledge. Using the National Carbon Accounting Toolbox (NCAT) FullCAM model has led to an innovative, event based carbon accounting model. This allows the Victorian Government to better understand how events influence carbon flows and stocks. The Victorian Government is responsible for the management up to 500 million tonnes of carbon in publicly managed land alone.

Fire can impact on soil carbon storages

In fire-prone landscapes, the role of fire in soil carbon sequestration is important and highlights the requirement to know the form as well as the quantity of carbon entering the soil. Fire, among other activities, directly modifies the form of carbon that enters the soil and influences soil carbon storage time, as well as causing an emission of stored carbon during the fire occurrence. This in turn influences other processes that rely on carbon within soils and overall system productivity. Additional work by the Victorian Government in ongoing validation and improvement of the RothC model which can be applied to the effects of fire is an important process in increasing our soil carbon knowledge.

The Victorian Government is committed to significant research to improve models for understanding soil carbon sequestration and its benefits and costs

In addition to building modelling capacity, the Victorian Government, in conjunction with, external researchers, and other State and Commonwealth agencies, is working on better understanding the environmental benefits of soil carbon sequestration. Specific research priorities include additional data from forests and other natural systems into NCAT modelling. This is a collaborative process led by the Victorian Government with the Commonwealth, other State agencies, and Universities. The Victorian Government is leading research in assessing changes in soil carbon stocks associated with environmental plantings and what this means for soil health and the role of fire and charcoal in forested environments.

This will result in better understanding of the potential impacts, and the potential rates and limits of sequestration of carbon in soils and associated environmental benefits.

Additional work is also needed to understand the value of any benefits derived by the environment. This is currently a major gap and addressing it would provide useful information, in conjunction with possible carbon trading benefits, on whether the costs of achieving additional carbon in Victoria's soils are worthwhile from an environmental point of view.

Terms of reference

(c) Consider methodologies for measurement of the effect of carbon sequestration including any potential issues associated with the measurement of benefits

Key Messages

- Currently, the only scientifically accepted method for measuring total soil carbon requires time consuming and costly soil sampling and laboratory analysis, and even this process is subject to variation.
- A preferred technique for measuring soil carbon is dry oxidation. Some alternative soil carbon measurement techniques in common use, such as wet oxidation, are less reliable as they do not account for all the relevant carbon fractions in the soil.
- New and improved soil carbon measurement technologies are being developed in Australia (by CSIRO) and overseas, but are not yet commercially available. These improved techniques are anticipated to be commercially available within the next three to five years.
- The Victorian Government is directly participating in the use and development of soil carbon measurement processes
- The limitations of existing soil carbon measurement techniques are not inhibiting some commercial providers from making soil sequestration claims for their agronomic products and land management practices.

Measuring total soil carbon sequestration

Laboratory measurements of soil samples at the beginning and end period is required to measure soil carbon sequestration

Two measurements of total soil carbon (including the error associated with the measurement) are required - one at the beginning and one at the end of the period being considered.

Currently, the only scientifically accepted method for measuring total soil carbon involves taking soil samples and subjecting them to laboratory analysis. The manner of soil sampling and sample processing is crucial to the validity of the final results.

Basic requirements include that:

- adequate numbers of appropriately located samples are taken to be representative of the area under consideration;
- soil depths are sampled appropriately and accurately;

- soil bulk density is measured to enable carbon measurements to be expressed as mass per unit area (normally tonnes per hectare);
- samples are handled and stored correctly prior to analysis; and,
- multiple soil samples are required for estimation of error.

The default soil depth for carbon accounting purposes is 0-30 cm. Post-sampling requirements include appropriate drying, separating, grinding and sub-sampling procedures. This ensures that the small amount of soil that will be subjected to laboratory analysis is representative of the whole soil sample. Standards for soil sampling and processing are well established in the professional soil science community, but neglect of basic requirements is common among non-scientists.

The two main scientific soil carbon measurement techniques are 'dry oxidation' and 'wet oxidation'. The widespread use of the dry oxidation technology is fairly recent and most soil carbon data worldwide is derived from wet oxidation methods. Wet oxidation methods are less suitable for soil carbon accounting because they may not measure charcoal completely or consistently across different soil types.

As stated, the definitive method for measuring total carbon in soil samples is dry oxidation using a high temperature induction furnace followed by measurement of the released carbon dioxide (using for example an infrared detector). A number of ASPAC (Australasian Soil and Plant Analysis Council)-accredited laboratories offer soil carbon analysis using this method in Australia.

However, the estimation of soil carbon sequestration is subject to significant sampling and measurement errors

Although the dry oxidation method for total soil carbon analysis is very accurate, estimation of soil carbon sequestration remains open to large inaccuracies if soil sampling and sample processing are not done with appropriate scientific rigour. Even with the best scientific protocols, estimation of soil carbon sequestration remains difficult because soil carbon (a) changes only slowly, and (b) is highly variable in agricultural and natural environments. This variation includes landscape, soil, natural disturbance, and climatic factors, which can have a stronger effect on soil carbon than land management practices do.

Total soil carbon consists of inorganic and organic carbon

Total soil carbon includes inorganic and organic carbon. Inorganic carbon (e.g. limestone) is found mainly in arid climates such as the Victorian Mallee and under normal circumstances is relatively stable. Organic carbon is amenable to change and is the pool of interest for soil carbon sequestration. Organic carbon itself can be divided into several fractions, or pools, differing in their susceptibility to decomposition – e.g. charcoal, humic material, resistant plant material, decomposable plant material and microbial biomass, listed in order of increasing decomposability. These fractions are represented in the RothC and National Carbon Accounting System (NCAS) models and therefore represent minimum standards around soil carbon modelling inputs.

Modelling total soil carbon sequestration

Mathematical models such as RothC in the NCAS are essential in assessing soil carbon sequestration

The use of mathematical models is also essential to assist with assessment of soil carbon sequestration across regions and land uses, including projections into the future. The pre-eminent soil carbon model in Australia is RothC which has been built into NCAS, the current Commonwealth Government model intended for use in any proposed emission trading scheme. RothC has been adapted and tested in Australian conditions and current research will result in further development. It can use the results of soil sampling and laboratory analysis to provide estimates.

Some businesses are claiming large soil carbon increases based on unverified methods

It is of concern that some commercial operations in Australia are claiming very large and rapid rates of soil carbon sequestration. These estimates rely upon unverified remotely sensed aerial measurement methods.

Measuring and modelling the composition of carbon

Composition of carbon pools essential to assess soil health, not just total stocks

Although total soil carbon is of primary importance for accounting purposes, knowledge of the composition of the carbon pools is crucial for making assessments of how land management or climate change will affect soil carbon with respect to soil health and carbon equilibrium. This is because the storage time of each fraction (in the soil) is highly variable. Importantly, the changes in the relative concentration of each fraction, irrespective of any change in the total soil pool, can have implications for the permanence of removal of CO_2 from the atmosphere.

New technology to determine soil carbon fractions are being developed

Mid Infra Red (MIR) spectroscopy has been developed by CSIRO to more efficiently and accurately measure soil fractions. However, the development of the models that underpin MIR require specialist, time consuming, and costly laboratory analysis, using wet chemistry and nuclear magnetic resonance (NMR) techniques. It is expected that this capability will be available in several research laboratories, including those of the Victorian Government, within several years.
New technology, such as mobile sensors based on Near Infrared Reflectance (NIR) spectroscopy, is also currently being developed and evaluated in the USA. This may eventually lead to more efficient methods of measuring soil carbon that do not require collection of soil samples.

Assessing the impacts of soil carbon sequestration

Increasing soil carbon can improve soil health. However the benefits are uncertain

Long-term loss of soil carbon can contribute to reduced agricultural productivity and greater environmental vulnerability through diminished biological, chemical and physical functioning of the soil. Conversely, soil carbon sequestration can improve biological, chemical and physical properties of soils (see terms of reference (a, b)). However, the extent to which carbon can be sequestered in soil, the extent to which the sequestered carbon will improve soil properties, and the extent to which improved soil properties will increase agricultural production, and benefit other environmental services, will all vary widely. This variation ultimately depends on factors such as the soil type, climate, management practices and the initial condition of the soil.

Currently not possible to accurately predict how management will affect soil carbon sequestration and other soil properties

The timeframe over which changes in carbon content are considered is also crucially important. With current knowledge, it is not possible to make meaningful predictions of how land management will affect soil carbon sequestration and how this will in turn affect other soil properties and agricultural production and environmental services.

Changes in carbon are accompanied by changes in other soil properties, such as nitrogen content

Measuring the direct effects of soil carbon sequestration is problematic because carbon changes are always accompanied by changes in other soil characteristics. For example, soil carbon sequestration is typically accompanied by nitrogen sequestration, and carbon loss is often accompanied by nitrogen loss. Either of these changes in nitrogen can be considered beneficial or detrimental depending on the circumstances.

Terms of Reference (d) Costs

Key messages

- There may be economic and environmental costs associated with the sequestration of additional and permanent soil carbon. The economic costs relating to new soil management practices are typically borne by the land manager, but some of the environmental costs are not and therefore represent externalities.
- There are significant transaction costs associated with trading soil carbon, due to the technical and logistical challenges of measuring changes in soil carbon content. In addition, carbon credits accrued by a land manager can revert to carbon liabilities, if the soil carbon content declines in any future accounting period.
- Some of the management changes, however, could reduce costs, For example, moving to a no till system is likely to result in lower fuel costs.
- Further research is required to quantify the environmental costs (and benefits) of soil management practices adopted to increase the soil sequestration, rates, especially their impact on net greenhouse gas emissions. For example, a life-cycle analysis is required to estimate the net emissions associated with a variety of biochar applications.

Increasing soil carbon sequestration can involve substantial economic and environmental costs

There are costs associated with the sequestration of additional and permanent carbon in Victorian soils, including economic and environmental costs. Some costs are borne by land managers while others are not and can therefore represent ‘externalities’ (*see glossary of market failure terms*). The main types of costs include costs associated with:

- changed land management practices
- the measurement of soil carbon
- the potential for future liabilities, if the carbon sequestered and ‘paid for’ is subsequently released into the atmosphere.
- environmental costs, such as the emission of other greenhouse gases such a nitrous oxide and methane.

Costs associated with changed land management practices

Management practices to increase soil carbon will involve costs

Management practices to increase soil carbon include environmental plantings, the development of biolinks, modified fire management, minimum tillage, stubble retention, green manure rotations in cropping (planting of leguminous crops), perennial pastures, farm forestry and the general reduction of disturbance. Many of these management practices will have costs and benefits, as described throughout the terms of reference.

Some costs of changed management practice can include:

- application cost of products to increase soil carbon, such as biological farming system products and/or biochar. Application to the soil is energy intensive, which may outweigh any carbon sequestration benefits;
- costs associated with stubble retention, which can be related to an increased incidence of pest and diseases;
- costs associated with farm forestry, and other water dependent land uses, which includes the direct costs of establishment and maintenance, but can include the cost of externalities such as ground water interception;
- opportunity costs of switching landscapes from food and fibre production to biodiversity plantings to deliver soil carbon sequestration and other ecosystem benefits;
- increased fire risk, and adverse carbon outcomes with reduced planned burning frequency;
- costs associated with rural/forest industry exclusion and modification of human resource requirements of land-use;
- increased costs of additional fertiliser inputs to ensure stable long term sequestration (see Box 2).

Box 2: Additional costs of soil carbon sequestration

To store carbon (C) stably in the soil, you need considerable amounts of nitrogen (N), phosphorus (P) and sulphur (S), in addition to that needed for crops. Humus, the stable soil organic matter arising from the breakdown of crop residues, will not build up in soil unless adequate amounts of these nutrients are available.

In humus the ratios of C to N, P and S vary a little, but are approximately: C/N = 10, C/P = 50, and C/S = 65. The ratios in cereal-crop residues are about five times larger for N and about 10 times larger for P and S. Thus, without additional N – and especially additional P and S – about 90 per cent of these crop residues are typically returned to the atmosphere as CO_2 within a year or two as the micro-organisms digest them on the way to form humus.

Humus contains about 60% carbon, so that every tonne of it contains 600 kilograms of carbon (equivalent to 2.2t CO_2), and about 60kg N, 12kg P and 9kg S. These amounts have to be locked up for as long as the carbon is stored, and their value may be approximated as the cost of replacing them with fertiliser, as illustrated in Table 1.

Carbon trading is normally based on a tonne of CO_2 equivalent, of which there are about 2.2 tonnes per tonne of humus. Thus, if the trading price for CO_2 is, say, \$20/t, then humus would be worth \$44/t. This is a quarter of the \$200 estimated for the value of nutrients locked up, as shown in the table below.

TABLE 1 VALUE OF N, P AND S LOCKED UP PER TONNE OF HUMUS

	Amount (kg)	Price/kg ($) spread	Approximate cost ($)
N	60	2	120
P	12	5	60
S	9	2	18
			≈ 200

[1]

Costs associated with carbon measurement

Soil carbon is technically difficult to measure over short timeframes

There are significant technical and logistical barriers to accurately account for soil carbon stocks. Soil carbon measurement is difficult and expensive, particularly over time-frames of less than a decade. This is because accounting has to be on a net-net basis, which measures the difference between the net rate of change in soil carbon at the start and at the end of the specified accounting period.

Therefore measurement costs will be high

The costs of measurement at either end of the accounting period are likely to be high. This implies the imposition of significant transaction charges for the potentially large number of farm businesses which might seek to enter the soil carbon market. The development of new technologies and the reduction of knowledge gaps is ongoing and an expensive process.

Carbon credits can revert to a liability

Due to accounting rules and impacts of climate's changes credits could be reversed in the future if soil carbon reduces

Under current international rules the sequestering of carbon via land management (whether through the growing of trees or soil management activities) needs to be both additional (ie would not have occurred in the absence of a human intervention) and permanent. As discussed earlier, carbon emissions from soil flux vary depending on climate conditions. The anticipated hotter and drier conditions in South Eastern Australia will make it harder to retain soil organic carbon levels in Victoria's agricultural landscapes. Carbon credits accrued by farm businesses for soil sequestration could become a potential liability, if the total amount of carbon stored declines over future periods.

Further, changes in management due to adaptation to Victoria's changing climate could also decrease soil carbon. For example, in response to increased climate variability, some dairy farmers are

[1] Grains Research and Development Corporation, Ground Cover Issue 76 - September - October 2008, The hidden costs of carbon sequestration

increasing their use of annual pastures and cultivation for forage instead of perennial pastures. These practices can lower the storage of carbon in the pastures involved. This could expose dairy farmers to a carbon liability had they opted to earn credits from soil sequestration.

Environmental costs

Efforts to increase soil carbon may result in increased emissions of N_2O or CH_4

Some land management activities aimed at sequestering carbon in Victorian soils at present could, in some circumstances, result in a net increase in greenhouse gas emissions (GHG). This perverse outcome can arise if, for example, additional fertiliser applied to encourage biomass growth leads to increased nitrous oxide production. However, there is an incomplete understanding of the net GHG effects associated with practices that aim to elevate the amount of carbon permanently stored in soils, especially on a life cycle basis. Further, the application of any agricultural product requires transportation and distribution on farm, which can involve additional GHG emissions. Details of a recent Victorian study into biochar viability are shown in Box 3.

Terms of reference

(e): possible harms and detriments

Key Messages

- The form of carbon added to soil influences the potential for harm, for both agricultural production and the environment.
- The linkages of some important biogeochemical cycles (such as nitrogen, phosphorous, and sulphur) with carbon need to be understood to avoid potential impacts on productivity.
- Inert carbon, while nominally not involved in biological processes, can influence other carbon fractions with the potential to harm productivity.
- Soil carbon fractions may be influenced by land-use change and some practices may reduce overall soil carbon storage.
- All costs need to be incorporated into any cost-benefit analysis.
- The Victorian Government, through its research linkages with research centres, the Commonwealth and State governments, various agencies, and Universities, is actively working on research priorities, management options, and a monitoring and reporting framework.

As noted in the introduction, the carbon cycle is intrinsically linked to nutrient cycles and other above and below ground biophysical and chemical changes. As such, increasing carbon in soils can stimulate changes in other cycles – some of which can have adverse consequences. These adverse consequences can include unwanted increases in nitrous oxide emissions or the immobilisation of nitrogen by microbial processes, and can be affected by the form of the soil carbon, climatic conditions and soil type.

Carbon and nitrogen

Carbon addition can increase non-CO_2 greenhouse gas emissions

Carbon and some other important nutrient cycles are intrinsically linked, such that as soil carbon increases, nitrogen increases. There are risks associated with the addition of external sources of carbon, whether nitrogen/phosphorus-rich, or not. Nitrogen rich carbon sources may potentially release greater quantities of non-CO_2 greenhouse gases, and if labile, increase potential for waterway eutrophication.

Carbon can reduce nitrogen availability for plants

Caution should also be used when adding carbon-rich substances to soils. The addition of carbon increases the carbon/nitrogen ratio and at a point between 20 and 30:1, the dominant process in the soil becomes the immobilisation of nitrogen by microbes. Immobilisation of nitrogen by these microbes increases competition between the plants and soil microbial communities. This ultimately decreases a plant's access to nitrogen, limiting productivity.

Inert carbon can influence other soil carbon fractions

The addition of truly inert sources of carbon, should not lead to changes in the biologically available carbon/nitrogen ratio, yet this risk is largely untested, but is based upon the mechanisms that limit microbial productivity. Even if the additive is largely inert, the addition could potentially influence other soil carbon fractions (such as dissolved organic), which could lead to greater flux of carbon into the atmosphere.

There are also risks associated with the potential agronomic and environmental benefits of biochar. The potential exists for biochar to influence nitrogen and other nutrient cycling or adversely influence non-CO_2 greenhouse gas emission rates. Risks also exist around reductions in crop yield, nutrient retention and availability, water retention, and soil biodiversity.

The Victorian Government and other agencies are assessing the impacts of biochar and carbon-rich external additives across a range of soil types and land management practices, in addition to the role of charcoal in natural systems.

Land-use and land-use change

Conversion of cropland/ pasture to forest should increase soil carbon

In general, conversion of cropland/pasture to forest leads to an increase in soil carbon, yet in some circumstances, conversion of cropland/pasture to forest can lead to a temporary decrease in soil carbon. Any loss is usually restricted to:

- the time taken to convert from cropland to forest,
- locations where soil carbon patterns are already relatively dynamic.

However, pre-planting actions can increase loss of carbon

Site preparation in the form of ripping, other pre-planting preparation, herbicide use, and reduced productivity as the plants establish (reduced leaf fall and root turnover) all contribute to loss of soil carbon, and may potentially induce other harmful effects (such as sedimentation in waterways).. Over time, soil carbon and soil stability may return to and then exceed previous levels.

Action to increase carbon may increase emissions resulting from additional fertiliser purchases

Increases in soil carbon stocks can also have other emission costs associated with them. An example of a high emission cost is the use of fertiliser to build soil carbon. These chemicals are mostly generated via industrial processes and have a significant emission profile associated with their production. Similarly, if water is used to irrigate for the purposes of increasing soil carbon sequestration, any benefit must be weighed against the loss of water for other uses or any energy cost of transporting the water.

Whether these costs are adequately incorporated into decision making in large part depends on how these other 'external' costs are captured by policy mechanisms. In the two examples industrial emissions and transport energy emissions any proposed

Victorian Government working to understand the full impacts of increasing soil carbon

The Victorian Government, in conjunction with CMA's, external researchers, and other State and Commonwealth agencies, is working on gaining a better understanding of the environmental harms and detriments of soil carbon sequestration.

Terms of reference

(f) Linkages with the proposed Emission Trading Scheme and other relevant Federal Government policies

Key Messages
• Worldwide, there are currently no mandated emissions trading schemes (ETS) covering soil organic carbon in agricultural landscapes. Soil organic carbon does trade, on a voluntary basis, on the Chicago Climate Exchange • On 24 November 2009 the Federal Government published the final National Carbon Offset Standard (NCOS), which identifies activities eligible for the generation of domestic voluntary offsets, including: o Inclusion of reduced emissions from agricultural soils (grazing and crop land management) o Soil carbon sequestration such as the application of biochar as part of Australia's future voluntary offsets market; • Soil carbon credits generated in this market will be subject to implementation of the new NCOS from 1 July 2010. • This type of abatement will potentially transition into any proposed ETS in the future, once such abatement is internationally recognised and provided that other ETS requirements are met. • The absence of a distinction between changes in soil carbon due to anthropogenic and natural causes poses a particular problem in the Australian environment. • The potential inclusion of biochar under an ETS is further complicated by policy uncertainty with regard to the point of obligation (farm versus the pyrolysis plant).

Worldwide, there are currently no mandated emissions trading schemes (ETS) covering soil organic carbon in agricultural landscapes.

No mandated soil carbon trading exists globally

Soil organic carbon does trade, however, on a voluntary basis on the Chicago Climate Exchange. For soil carbon to be included in a carbon trading scheme it would need to satisfy a number of conditions. These are discussed later in this section.

ETS coverage and soil carbon sequestration opportunities

The Commonwealth Government and Shadow Cabinet agreed in November 2009 to include soil carbon in Australia's voluntary offset market.

On 24 November 2009 the Commonwealth Government published the final National Carbon Offset Standard (NCOS). The NCOS identifies reduced emissions from agricultural soils (grazing and crop land management) and soil carbon sequestration. For example, the use of biochar as eligible activities for the generation of domestic voluntary offsets. Soil carbon credits generated in this market will be subject to implementation of the NCOS from 1 July 2010. This type of abatement will potentially transition into any proposed emissions trading scheme in future, once such abatement is internationally recognised and provided that other trading requirements are met.

This will require development of a new policy and legal framework to ensure that soil carbon credits are based on a rigorous and defensible methodology. This will be particularly important in the case of soil carbon, where much of the debate to date has been about the adequacy of existing science, and the ability to accurately project carbon sequestration in different types of soils.

Recognising that key policy directions on this issue are currently being developed primarily at the national level, this submission focuses on:

- Explaining the science of soil carbon sequestration, its role in the carbon cycle, and its potential contribution to greenhouse gas abatement;
- Outlining existing Victorian Government responses to the issue; and
- Identifying key issues that will need to be resolved before soil carbon can effectively integrated into the national carbon market.

Soil sequestration in agricultural landscapes and Kyoto Article 3.4

An ETS would be designed to conform to Kyoto Protocol accounting rules…

Any proposed emission trading scheme would be designed to conform to all Kyoto Protocol rules. This is important for the Commonwealth Government to ensure that Australian emissions units (equivalent to one tonne of carbon dioxide) are equivalent to any other accredited Kyoto unit and hence fully fungible on international carbon markets.

.. and Australia has not opted into Agricultural Lands component of Kyoto

The previous Carbon Pollution Reduction Scheme (CPRS) draft legislation did not mandate soil carbon monitoring and reporting as Australia has not opted in to the Agricultural Lands component of Article 3.4 of the Kyoto Protocol, which accounts for carbon sinks in soil and non-woody vegetation. Additionally, soil carbon monitoring and reporting is not expected to be included in any proposed emission trading schemes. However, soil carbon could be included in an emission trading scheme even without Article 3.4, potentially resulting in an emissions deficit in our Kyoto obligations. This Article allows *Annex One* countries to include carbon sinks in soil and vegetation, both above and below ground on crop and grazing land in their national greenhouse gas inventories.

The Commonwealth Government chose to not 'opt in' to Article 3.4 of the Kyoto Protocol, due to a concern that it could incur a net liability. Australia rejected adoption of this Article in 2001 for calculation of its national inventory because it included drought and bushfire as sources of anthropogenic emissions.

Article 3.4 not included due to high risk of liability

The absence of a distinction between changes in soil carbon due to anthropogenic (farming activities, planned burns) and natural causes (drought, bushfire) poses a particular problem in the Australian environment. A region with large natural variations in soil carbon due to high climate variability (e.g. Australia), runs the risk of having a very big and essentially uncontrollable emissions liability at the end of any specified commitment period depending on the season (Pannell, 2008).

Any proposed emission trading scheme reforestation legislation would also be expected to exclude forestry soil carbon. The Commonwealth Government's reason for this includes that forest soil carbon is complex to measure; takes long periods of time to show change; and is likely in the long-term to be a minor source or net carbon sink.

Considerations for the design of a soil carbon accounting and trading system

A Commonwealth Government publication on soil carbon management and trading (BRS, 2008) noted the following in relation to the design of a soil carbon accounting system:

'There are elements of measuring and monitoring changes in organic soil carbon that need to be better understood if it is to have a role in carbon trading scheme', including:

- the limits to storing carbon for long times in Australian soils under changing climates,
- management practices that can demonstrably increase sequestering of organic carbon in soils,
- effects these practices have on the delivery of other ecosystem services, including food production,
- the life cycle impact on greenhouse gas balances of these practices,
- practices that increase the level of stable carbon fractions deeper down a soil profile.

Other factors to consider for including soil carbon into an accreditation scheme include:

- additionality and permanence;
- verifiable accounting systems;
- accounting for non-anthropogenic and anthropogenic emissions sources;
- how to manage changes in debits and credits for landholders;
- the rules may change;
- variability in performance over space and time and the costs to monitor & report (transaction costs);
- institutional change – adapting to new services (public good).

Terms of reference

(g): linkages with existing Victorian Government policies

Key Messages

- Soil carbon research, notwithstanding significant work on soil organic matter, is relatively new. The Victorian Government is undertaking work to address gaps in knowledge.
- Victoria's *Catchment and Land Protection Act (1994)* provides a useful framework soil health and soil carbon sequestration.
- Victoria's *Environment Protection Act (1970)* has controls to prevent the contamination of land.
- The Victorian Government's Future Farming Strategy, which includes the Soil Health Strategy, builds upon the Sustainability Action Statement.
- The Land and Biodiversity White Paper sets out the Government's agenda for land, water and biodiversity at a time of climate change. The White Paper calls for more research into soil carbon.
- Victoria's *Sustainable Forests (Timber) Act 2004* requires the establishment of the criteria and indicators for sustainable forest management, which specifically includes soil resources and contribution to carbon cycles, including soil carbon.

Victoria recognises the potential of soil carbon

Victoria already recognises the potential importance of soil carbon, both from a climate change as well as more general soil health perspective. Reflecting the relatively new and incomplete nature of the underlying science as well as the important role the Commonwealth will now play in setting policy, policy responses at the State level have so far focussed primarily on:

- investing in more research, to get a better understanding of soil carbon sequestration processes;
- sponsoring of on-ground pilot projects and the testing of practical soil management techniques, particularly in farming / agricultural settings; and
- designing new incentive systems that will encourage land managers to not only sequester more carbon in soil, but to do so in ways that can generate additional private and public benefits (e.g. Improved soil productivity for farmers; additional environmental benefits for the community).

Some recent key policy initiatives are outlined below.

The Catchment and Land Protection Act provides the basis for much existing action on soil carbon.

Catchment and Land Protection Act 1994

Under the *Catchment and Land Protection Act 1994*, Victoria is divided into ten catchment regions with a Catchment Management Authority (CMA) established in each region. This will be reduced from ten to five larger CMA's as recommended in the State Government's 2009 Land and Biodiversity Whitepaper: Securing our Natural Future. The CMAs form a major part of the framework for achieving sustainable management of Victoria's land and water resources and many have a soil health component to their reporting. CMAs are involved in ongoing land management and research around soil carbon sequestration.

The Environment Protection Act has controls to prevent the contamination of land.

Environment Protection Act 1970

Under the *Environment Protection Act 1970*, Section 45, any products applied to the land must be fit for purpose and not cause aesthetic or chemical contamination of land. The source of the material and the process used to generate the product will significantly alter the risk of contamination. For example, bio-char derived from source separated green wastes has a lower risk of contamination than those derived from mixed waste streams.

Victorian Government is developing a soil health framework under its Future Farming Strategy

Future Farming Strategy

The Victorian Government's Future Farming Strategy includes a new Victorian Soil Health Framework which is scheduled for release in 2010 and will build on the Victorian Government's work already undertaken under the Sustainability Action Statement. The Future Farming Strategy also commits under "Planning for Climate Change" to provide accessible and relevant information and research, and develop tools and techniques to expand understanding about carbon and bioenergy markets and identify barriers faced by Victorian farmers in reducing their emissions.

Victorian Land and Biodiversity White Paper sets out Government's agenda for land, water and biodiversity.

Land and Biodiversity White Paper

The Victorian Government released its Land and Biodiversity at a time of Climate Change White Paper in December 2009. The White Paper sets out the Government's agenda for land, water and biodiversity at a time of climate change. Key objectives include:

- building ecosystem resilience across Victoria;
- managing flagship areas to maintain ecosystem services; and
- improving connectivity in areas identified as biolinks.

To achieve this vision, the Government will implement a comprehensive reform program, including

- increasing Government's effectiveness, by reforming and realigning Victorian Government processes and institutions;
- Fostering environmental markets and leveraging investment;

- Supporting community action; and
- Building health and resilient ecosystems across the landscape.

The White Paper advocates a risk management approach for soil, with an emphasis on further building our knowledge of soil processes as a basis for natural resource management. The White Paper proposes better integration of soil considerations into environmental modelling tools; regional catchment management strategies , investment processes and farm management planning.

White Paper calls for more research into soil carbon .

The White Paper also specifically recommends further research directed towards increasing understanding of carbon in Victorian soils and identification of areas where soil management can deliver public benefits, including carbon sequestration.

Sustainable Forests (Timber) Act 2004

The potential importance of soil carbon in the context of established native forests, from both a climate change and general soil health perspective, is already recognised in Victoria. For example, the *Sustainable Forests (Timber) Act 2004* requires Victoria to establish criteria and indicators for the sustainable management of Victoria's State forests. The Victorian Government recently introduced its *Criteria and Indicators for Sustainable Forest Management*. The framework was developed with the assistance of key experts, Government partners, and in consultation with the community. It is consistent with the international Montreal Process (1995), and complements the Framework of Regional (Sub-National) Level Criteria and Indicators of Sustainable Forest Management in Australia.

The 45 criteria and indicators provide the Victorian Government with considerable forest-related monitoring and information reporting, providing a means to quantify our success in sustainable forest management. It is geared to ensuring more sustainable long-term management of Victoria's native forest estate and to help inform Victorians on progress. Performance against each indicator is reported on a five-yearly basis through Victoria's *State of the Forests Report*. Soil carbon features explicitly under two of the framework's key criteria, and is the subject of three specific indicators shown in Box 4:

Box 4 Criterion 4: Conservation and Maintenance of Soil and Water Resources	
	Indicator 4.1 Area and percentage of forest by activity type systematically assessed for risk to soil attributes
Criterion 5: Maintenance of Forest Contribution to Global Carbon Cycles	
	Indicator 5.1 Total forest ecosystem biomass and carbon pool by forest type, age class, and successional stages
	Indicator 5.2 Contribution of forest ecosystems to the global greenhouse gas balance

Terms of reference

(h) options to support benefits of soil sequestration

Key Messages

- The Victorian Government is developing a Soil Health Policy Framework as part of its Future Farming Strategy (2008) which will guide the development and implementation of research into soil health, including soil carbon. The policy will acknowledge the importance of managing chemical, physical and biological properties of soil as an ecological system.

- A better understanding of complex, interactive soil and related systems across whole farm and forestry systems over extended periods is required to enable land managers to operate more efficiently in commodity, carbon and other ecosystem markets. It will be important to understand any unintended adverse impacts of sequestering soil carbon, such as increasing emissions of nitrous oxide.

Options are available for the storage of carbon in soils

There are a number of options farmers, communities, public land managers, and governments more generally (Commonwealth, State and local) could consider to help achieve efficient and effective storage and management of carbon in Victoria's soils.

The role for government is focused on areas of market failure

In general, the potential role of government regarding soil carbon sequestration should be focused on where markets and private decisions are not able to provide efficient and equitable outcomes for the community, and where the net benefits of government action are greatest.

Properly functioning markets are generally effective mechanisms for efficiently using inputs and allocating resources to where they are most valued. This includes facilitating the flow of goods and services across the economy, which may include agricultural products, amenity values or ecosystem services such as carbon sequestration. The creation of a carbon market would effectively put a 'price' on carbon and seek to encourage the more efficient use and allocation of Australia's resources, recognising that GHG emissions impose a cost onto society that has in the past been ignored. This carbon price will be an important signal to land managers as to how much soil sequestration to generate (given the costs, including opportunity costs, of doing so).

Assuming a carbon market, decisions on soil sequestration are most likely to be best made by land managers who have knowledge of their soil and climate conditions, and have a direct stake in how best to use the soils they manage.

However, where the operation of markets and private decisions are impeded, decisions on soil carbon sequestration can be distorted, creating a potential additional role for government.

The following identifies where markets (even including a carbon market) are possibly failing, which could provide a rationale for government response. In all cases the benefits of government actions should be greater than the costs to the community.

Key areas where market failures may exist include:

- gaps in research and development regarding the basic science of soil behaviour;
- gaps in the measurement of carbon; and
- information failures.

Gaps in soil carbon sequestration science

Soil science is complex and considerable research gaps remain.

The Victorian Government's scientific research to date has found relatively limited capacity for sequestering carbon in Victorian cropping soils. However, gaps remain in the science and further research is needed. The gaps include scientific knowledge regarding:

- carbon storage in soils;
- carbon fractions in soils;
- role of natural soil charcoal in fire-prone landscapes;
- external addition of carbon-rich substances to soils, such as biochar;
- measurement of soil carbon;
- management practices that can demonstrably increase sequestration of organic carbon in soils; and,
- life-cycle impact on greenhouse gas balance of management practices.

Governments at all levels have potentially important roles in supporting basic research

Where this involves 'basic' research which cannot easily be appropriated by any single private individual and/or company (i.e. the results are both non-excludable and non-rival), there can be a strong case for government investment. In reality there is often a mix of public and private benefits to soil carbon research and governments will seek to co-invest with private companies to the extent warranted by the potential public benefit. As much of the research is of national/international significance, the Commonwealth Government largely leads public investment. Yet Victoria is leading some research in this area, in cooperation with the Commonwealth and other State Governments.

Information failures in the Australian market for soil conditioners and carbon trading

Despite uncertainty, a significant number of farmer's plan to change practices to increase soil carbon

Significant uncertainty surrounds the potential of increasing land-based carbon sequestration and the regulatory regimes that would allow changes in soil carbon to be accounted for in policy frameworks. However, many primary producers are planning to increase their soil carbon in response to climate change. The report, "Understanding farmer knowledge and attitudes to climate change, climate variability and emissions trading", prepared by WIDCROP in September 2009, found that of 1,500 Victorian primary producers sampled, 53.9% plan to change their soil management practices to increase soil carbon due primarily to financial and environmental benefits.

A concern is that numerous sellers of alternate systems are making unsubstantiated claims regarding soil carbon

Climate change and the potential for soil sequestration and potential economic return has generated many claims from organisations and businesses promoting various products or techniques. Many sellers of alternative systems, for example biological farming, are making ambitious claims regarding the soil health and agricultural productivity benefits of their products or services, including reduced production costs. These claims have rarely been verified by peer reviewed science. Further, the long term effects of applying their Biological Farming Systems (BFS) products to soil are often untested and there may be unintended production or off-site impacts.

There may be a role for government to address information symmetry in these cases

Given the interest in soil carbon sequestration there is a risk of primary producers and other interested parties investing in soil carbon products and activities in the absence of sufficiently reliable information. This could result in inefficient practices. There is a potential role for government to explore options for ensuring land managers are not denied useful information due to market failures reflecting the public good characteristics of information or asymmetric nature of it (recognising that gaining useful information has costs).

Box 5 outlines the potential role of government in soil sequestration.

Box 5 Summary on the role of government in soil sequestration on farms (see glossary of terms for market failure)

- In general, farm businesses are best placed to make a decision regarding sequestering carbon in their soils. By responding to their own needs and preferences, farm businesses can develop soil sequestration responses that are business specific, locally-appropriate and cost-effective.
- The role for government in facilitating farm businesses to sequester soil carbon largely relates to addressing inefficiencies in markets, regulatory and institutional arrangements, along with ensuring the community's environmental objectives are achieved. In particular, there may be a role for government where:
  - there is compelling evidence of market failure, including 'information failures', 'public goods', 'externalities', and 'market power'; or
  - existing government policies, regulations or investments (inadvertently) pose unnecessary impediments to efficient and effective soil sequestration.
- In all cases the public benefits of government intervention must outweigh the anticipated costs to the community as a whole. This assessment needs to account for any beneficial or adverse externalities that might occur in response to such action (such as effects on biodiversity), and appropriate responses to these.
- The level of government responsible for an action should be at that level that can deliver the greatest net community benefits, in terms of outcomes, cost and desirable process.
- In the event that government intervention is deemed beneficial, soil carbon policies should, among other things, satisfy good policy development criteria such as the development of clear objectives, an assessment of alternatives, and a transparent evaluation framework before implementation.

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Glossary of terms associated with market failure and policy impediments

The key characteristics of market failure are explained below.

- **Externalities** arise when a firm undertakes activities that impose costs (a negative externality) or confer benefits (a positive externality) on others and no compensation is paid or received. For example, a negative externality is generated if pollution is discharged into a river and this affects downstream users. An example of a positive externality is weed control – weed control on one farm provides benefits to neighbours. Externalities are often called spill-over benefits and costs, and often persist because there is no efficient market to account for them.
- **Information asymmetry** can occur when one party to a transaction has information which is not available to the other party (hidden information) or one party can influence the outcome of a transaction by behaving in a certain way that is unobservable to the other party (hidden action) and this results in inefficient decisions. The seller of a used car, for example, has more knowledge about the quality of the car than potential buyers and can use this superior information to obtain an advantage. This type of asymmetry can distort behaviour and causes inefficiencies in the economy if low cost market responses (such as third party vehicle inspections) are not available.
- **Market power** occurs when a firm can influence the price / quantity of goods in a market for increased profits, such that the allocation of resources in that market is inefficient.
- **Public goods** are non-excludable (suppliers cannot exclude anyone from obtaining the good or service) and non-rivalrous (one person's consumption is not limited by others) in their consumption. Examples include national defence and basic research.
- **Policy impediments** refer to government policies, including regulations, institutional arrangements and investment decisions that are unnecessarily restricting the efficient decisions of businesses or individuals. This might occur because the business or physical environment has changed such that a policy is no longer optimal or would benefit from a change in design or implementation.