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A role for Agriculture in Australia's domestic 'cap and trade' scheme

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Executive Summary

The official National Carbon Accounts for Australia shows that agriculture is the second highest emitting sector of the economy   Agriculture's accounts include the direct emissions of green house gasses from livestock, fires, manure, fertiliser use and changes in carbon pools both above and below ground. An accurate assessment of net green house gas from a nation requires a considerable breadth (i.e. activity data) and depth (i.e. scientific data) of information.

The IPCC recognises that nations may not have all the hard data required for an accurate estimate for sectors so three 'Tiers' of assessment are allowable. The Australian National Carbon Accounts use the 'Tier 1' assumption for estimating changes in above and below ground, carbon pools for 'cropland' and 'grassland'. The IPCC 'Tier 1' assumption for these pools is 'no net change', or zero emissions / sequestration. Therefore Australia's accounts **do** include the net gain /loss of soil carbon but with the estimate of the tonnes of CO2e being zero. Unfortunately there has been so little research on the affect of farming practices on soil carbon we can not estimate this major component of our national green house gas emissions with any accuracy.

Australia must make a large investment into research on the carbon cycle in 'cropland' and 'grassland' to

a) Meet our commitments under the Kyoto Protocol
b) Increase sequestrations of our farming systems

The estimate of changes in soil carbon is likely to represent the single largest 'uncertainty', or error, in Australia's accounts. We can not at this time estimate whether there is a net sequestration of carbon in the soil, or a net emission. Broad acre cropping and grazing on non irrigated land in Australia covers 470 million hectares. If there was an average of 0.5 tonne CO2e per hectare per year emission from a loss of soil carbon then Australia's total emission would increase by 41%. An average of 0.5 tonne CO2e per hectare per year sequestration of soil carbon would decrease Australia's total emission by 41%.   A change of 0.5 tonne CO2e per hectare per year is well within the range of long term trials in agricultural areas of Australia.

To comply with the Kyoto Protocol Australia must adopt the continuous improvement in our accounts as required under the IPCC best practise guidelines. Research on agriculture sinks and sources must be a top priority to fulfil our commitments under

the Kyoto Protocol. We must also measure our farm sources and sinks so that farmers can learn how to lower their emissions. If you can't measure it, you can't manage it.

The limited research to date has shown that pastures tend to build up soil carbon more than cropping, with perennial pastures more effective than annual pastures. Some cropping methods build up soil carbon whiles others reduce soil carbon. Research is starting to emerge showing that soil biology may have a large affect on how much, and for how long, carbon is stored in the soil.

To improve the accuracy of Australia's Nation Carbon Accounts research is required on…..

a) Nett sequestration/emission rates for the major farming method for each region
b) The area of each farming method for each region

Specific research is required for soil or vegetation carbon sequestration to be traded as green house gas off sets. To support trading research is required on…..

c) The most cost effective farming methods to sequester carbon in broad acre agriculture
d) Cost effective methods for measuring, accrediting and auditing net carbon sequestration

Sequestering carbon in trees and other woody vegetations (Article 3.3 sinks) is more readily accepted than sequestration in the soil under crops and pastures (Article 3.4 sinks). This view is based more on the fact that you see trees but not soil carbon, rather than on the actual amount of carbon stored. Currently timber crops for lower rainfall (< 600 mm) farming regions are mostly not profitable. Broad acre agriculture has the potential to sequester far more carbon than the agroforestry industries in Australia.

If Australia's cap and trade scheme allowed timber crops under Kyoto Article 3.3 but excluded cropping and grazing sinks under Article 3.4, there could be the perverse outcome of a net increase in Australia's Green House Gas emissions.

Cattle, sheep and goats produce methane gas, a green house gas, due to the digestion of the feed by microbes in the rumen. A simplistic view is a reduction of the numbers of livestock would result in a reduction of Australia's total GHG emissions. However changes in livestock farming methods could both increase Australia's meat production and at the same time reduce net emissions. A complete green house gas audit on two farms, using perennial pastures in innovative ways, calculated a net sequestration of 25 and 29 kilogram of Carbon Dioxide Equivalents for each kilogram of produce sold off the farm.

For a comprehensive coverage of Australian agriculture a major research effort is required. While government will need to play a central role in that research effort, it may not have to cover the entire cost. If carbon credits were sold from farm land they would in one sense be just another farm commodity and could have a 'research levy' collected when farmers sell their carbon credits.
The size of this carbon levy pool could be considerable. If we assume an average

- 0.5 t CO2e/ha/year were sold as off sets (i.e. 136 kg C/ha/year),

- a 2% levy on a sale price of $20 /t,
- 235 million hectares of agriculture land (i.e. 50% of potential land),

would result in $47 million per year available for research.

Considerable progress could be made by broadening the scope of existing agriculture research projects to included measurements of carbon sinks and sources. The Federal government should supply the additional funds to support this activity as it will be a direct financial benefactor of the resulting reductions in the Australia's net emissions under the inter-national 'cap and trade' system of the Kyoto Protocol.

Big business is interested in investing in carbon off sets in the medium and low rainfall agriculture regions and the rangelands. There is some reluctance to commit until the details of the domestic 'cap & trade' scheme are known. Major mineral and energy resources companies are already investing, or considering investing, in carbon farming research.

Farmers are likely to be the largest source of data for research. Farmers currently collect and analyse soil samples to help make fertiliser decisions. Contractors with coring rigs are being used more widely to collect farmers soil samples. Sampling contractors and commercial soil testing labs could be accredited to use standardised sampling protocols which would give a reliable estimate of soil carbon pools.

For a complete account of carbon pools an estimate of the amount of carbon in the vegetation is also required. Remote sensing technology using satellites has already been commercialised for measuring the amount of dry matter in annual pasture paddocks. Emerging satellite technologies will improve the capacity for remote sensing of vast areas of land at low cost. Further investment by government will be needed to develop these tools and take advantage of new technologies as they emerge.

The farmer's soil tests and remote sensing data could be added to a centralised data bank which would allow a very accurate assessment of changes in Australia's agriculture carbon pools. The data could also be used for the calibration of models such as RothC.

A coordinated approach is required into research and development on Green House Gas issues for Australia. There must be standardised approaches to data collection, analysis and modelling so as to:

a) allow Australia to use a Tier 2 or Tier 3 assessment of 'Agriculture' net emissions
b) develop national standards for measuring, selling and auditing off sets from agricultural land.

Carbon pool models such as RothC are essential to underpin our National Carbon Accounts and for the trade of off sets. Direct measurements of carbon pools will never be viable at the scale required. Models allow simpler measurements to be used to estimate changes in carbon pools. These models are empirical and there accuracy depends on the volume and quality of data used in their construction.

A range of farming technologies are being developed and adopted in the Northern Ag Region of WA that can adapt to lower and more variable rainfall, and sequester carbon at the same time. Some of these radical technologies are still in the very early stages of development. The very rapid decline in rainfall in the Northern Ag Region of WA (25% this decade) means the gradual 'evolution' of farming systems may be too slow to prevent the collapse of agriculture in the low rainfall districts. Including carbon credits from crop and pasture land in our cap and trade scheme could be the catalyst for a 'revolution' in farming practises. The key factors for a 'revolution' in farming methods are the threat of immanent failure, pioneering farmers, dedicated researchers, collaborative R&D and substantial funds for an intensive period of R&D.

There are a number of challenges to marketing Article 3.4 carbon sinks from broad acre agriculture. Direct measurements of changes in soil and vegetation carbon pools using scientific methods will be too expensive for commercial trading of carbon credits. Carbon can be estimated at lower cost by using indirect methods that are calibrated and validated at research sites using detailed research methods. A trading system based on carbon pool models should reduce the uncertainty and cost of measuring farm carbon credits. The risk from models would be reduced by periodic direct measurements of the carbon in the paddocks marketed. The data from paddock sampling could be then fed back to refine the models. This iterative approach would progressively reduce the uncertainty over time.

It is recommended that Article 3.4 sinks should be allowed to be traded in an Australia domestic 'cap and trade' scheme using a combination of

a) **modelled changes in carbon pools**
b) **a 'margin of error' discount based on the uncertainty of the estimate**
c) **adjustment of the tonnes sold based on periodic soil testing**

Marketing mechanisms are needed to deal with variability in carbon pools in crop and pasture land over time. Schemes that can deal with this include Pay As You Go (PAYG), Variable Length Contracts (VLC) and Carbon Annuity Accounts (CAA). The financial institutions could also offer marketing options that provide up front payments as finance for farmers to change their systems.

It is recommended that Article 3.4 sinks be initially traded as gross carbon sequestration in the soil and vegetation until there is enough data and accounting systems in place to move to a net sequestration based on a full farm business carbon audit.

Under a full farm carbon auditing scheme farmers would not be required to off set all of their emissions but would be given a 'cap' or quota. The two main methods considered for allocating caps are 'Grandfathering' where caps are given free to businesses based on their past level of emissions or auctioning of the caps where market forces dictate the allocation between business and sectors. The problem with Grandfathering is that existing businesses have an unfair advantage over business that may start in the future and won't get a free allocation of emissions. However as the area of land is fixed, the allocation of emission quotas to existing farms based on the area would not restrict the expansion of agriculture. A fully open emission auction scheme may have an adverse outcome in that many cash strapped smaller farmers may not be able to compete in the market place. Even a closed auction within the farm sectors could see corporate farmers acquiring very large caps which could then be used to dominate and distort the farming sector.

It is recommended that the allocation of emission quotas to agricultural businesses be determined centrally by government rather than by auction. The allocation by government should be based on a formula accounting for area farmed, rainfall / region and land use class (e.g. free hold vs. lease hold)

For carbon credits from agricultural land to be traded there is the need for legislation to validate the ownership of the carbon sequestered. Recent 'carbon rights' state legislations gives certainty to the ownership of carbon sequestered for freehold land owners but not for lease holders, such as pastoralists. There are also differences between states in laws relating to the rights and management of lease hold land.

There is a need for a uniform approach by the states to the ownership of carbon sequestered on leasehold land due to the management actions of the lease holder.

The role of agriculture in Australia's net emissions of Green House Gasses

The official National Carbon Accounts (NCAS) for Australia shows that agriculture is the second highest emitting sector of the economy. Our National Carbon Accounts are prepared following the Inter-governmental Panel on Climate Change (IPCC) 'Guidelines for National Greenhouse Gas Inventories'. The IPCC provides the detailed accounting methods for each sector of the economy. The accounts are constructed from 1) estimates of the scale of activities in the sector that either emit or sequester green house gasses and 2) scientific calculations for converting those activities in to tonnes of Carbon Dioxide equivalents (CO_2e).

Agriculture's accounts include the direct emissions of green house gasses from livestock (methane), fires (NO_2 etc), manure (Methane) and fertiliser use (NO_2). The IPCC guidelines also include the estimation of changes in carbon pools both above and below ground. When carbon pools in the soil and vegetation are reduced the carbon is released to the atmosphere as CO_2. This release of CO_2 is counted as an emission or 'source'. Carbon pools in the soil and vegetation can also build up due to plants removing CO_2 from the atmosphere. This removal of CO_2 gas is regarded as sequestration or a 'sink'.

An accurate assessment of net green house gas from a nation requires a considerable breadth (i.e. activity data) and depth (i.e. scientific data) of information. The IPCC recognises that nations may not have all the hard data required for an accurate estimate. Where country specific data is missing the IPCC provides standard assumptions so the accounts can be completed. The IPCC allows for 3 'Tiers' of accounting to be used that reflect the availability of data for each specific nation.

The IPCC 'Tier 3' level of accounting has the least uncertainty. With 'Tier 3' the country uses detailed national data of the size of an activity (e.g. ABS type statistics on numbers of animals, fertiliser usage, areas of specific crop and grazing practise etc.) combined with scientific conversion factors that have been validated by local research. The 'Tier 2' calculations are used where some detailed information is available but other data is missing. In this case the accounting is done with a mix of the countries own data and IPCC assumptions. 'Tier 1' accounting uses simple assumptions provided by the IPCC when a country has little hard data of its own.

The IPCC 'good practice guidelines' require countries to invest in research and statistics gathering so they are continually improving the accuracy of their national accounts.

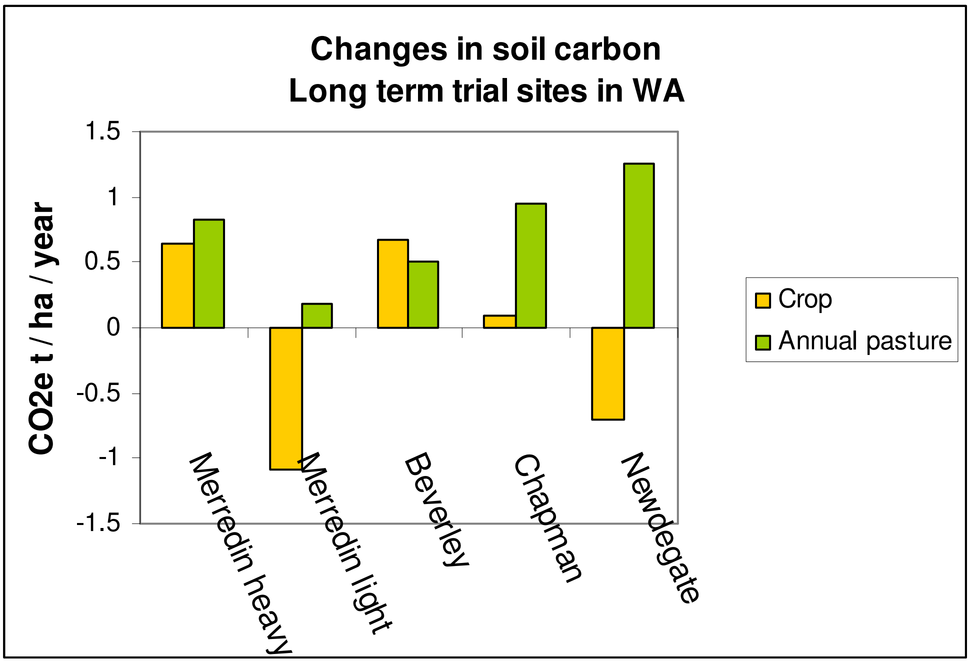
The Australian National Carbon Accounts use the 'Tier 1' assumption for estimating changes in above and below ground, carbon pools for 'cropland' and 'grassland'. The IPCC 'Tier 1' assumption for these pools is 'no net change', or zero emissions / sequestration (2006 IPCC 'Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use'). Therefore Australia's accounts do include the net gain /loss of soil carbon but with the estimate of the tonnes of CO_2e being zero (AGO 2005). For this reason many people mistakenly believe soil carbon is not included in Australia's accounts. Unfortunately there has been so little research on the affect of farming practices on soil carbon we can not estimate this major component of our national green house gas emissions.

Australia must make a large investment into research on the carbon cycle in 'cropland' and 'grassland' to

c) **Meet our commitments under the Kyoto Protocol**
d) **Increase sequestrations of our farming systems**

The estimate of changes in soil carbon is likely to represent the single largest 'uncertainty', or error, in Australia's accounts. We can not at this time estimate whether there is a net sequestration of carbon in the soil, or a net emission. Broad acre cropping and grazing on non irrigated land in Australia covers 470 million hectares (AGO 2005). If there was an average of 0.5 tonne CO2e per hectare per year emission from a loss of soil carbon then Australia's total emission would increase by 41%. An average of 0.5 tonne CO2e per hectare per year sequestration of soil carbon would decrease Australia's total emission by 41%. A 0.5 t CO2e per hectare per year change in soil carbon only represents a 136 kg per hectare per year change in actual carbon. The 136 kg per hectare per year of carbon would represent ~5% of the carbon in a typical annual pasture or crop.

Figure 1. Changes in soil carbon content (t CO2-e/ha) after land use change to either continuous cropping or pasture for five sites in south-western Australia (from Harper et al, 2007; data from Skjemstad and Spouncer, 2003).



A change of 0.5 tonne CO2e per hectare per year in soil carbon pools is well within the range of long term trials in agricultural areas of Australia (Table 1, Figure 1). A sequestration rate of 0.5 tonnes CO2e per hectare per year is also not unachievable for the range lands. Paired paddock sampling (Figure2 & 3) on 'Cheela Plains' station in the Pilbara of WA has shown an increase in soil carbon and ground litter of 0.3 tonnes CO2e per hectare per year due to changing from traditional set stocking to rotational grazing. This does not include the substantial increase in the carbon build up in the perennial grasses and shrubs under rotational grazing (nb: insufficient funds to measure the plant biomass). The 'Cheela Plains' results are particularly promising as 7 of the 9 years since adopting the rotational grazing have been below average rainfall, including the worst 4 year drought on record.

Figure 2; Soil Organic Carbon in the top 10 cm from 'over the fence' paired sites from a) 'Inside Cell' with intense rotational grazing or b) 'Outside Cell' with traditional set stocking at 'Cheela Plains', Paraburdoo on 11 July 2007. (T Wiley, P Smith and M Stockdale 2007. Unpublished data)

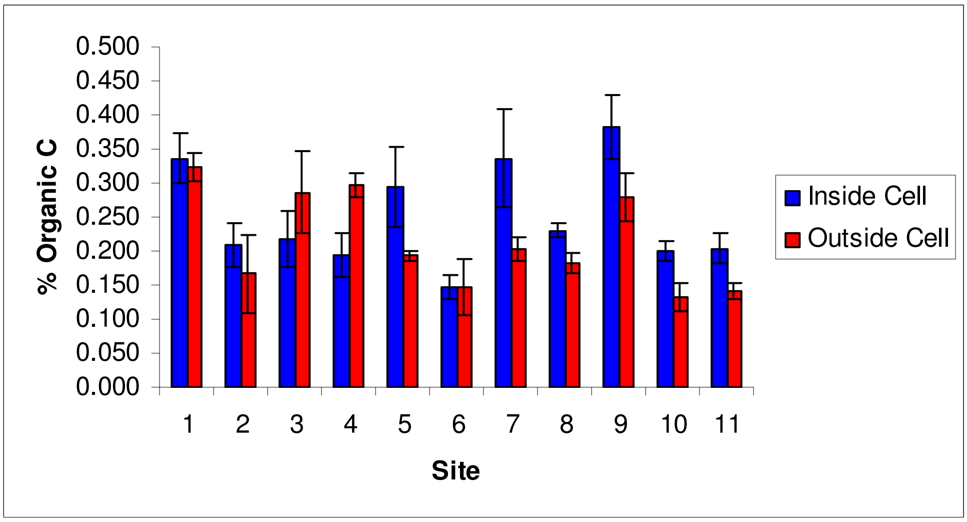
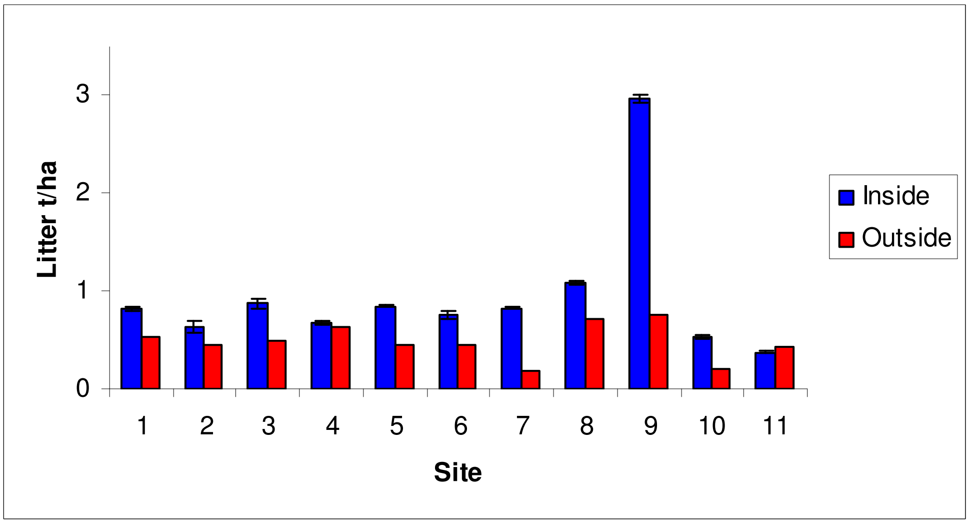


Figure 3; Surface litter dry matter from 'over the fence' paired sites from a) 'Inside Cell' with intense rotational grazing or b) 'Outside Cell' with traditional set stocking at 'Cheela Plains', Paraburdoo on 11 July 2007. (T Wiley, P Smith and M Stockdale 2007. Unpublished data)



Some have argued that we should exclude soil carbon from Australia's National Carbon Accounts because of the risk that it turns out that there is a loss of carbon on average across our agricultural land. However to comply with the Kyoto protocol we must adopt the continuous improvement in our accounts as required under the IPCC best practise guidelines. Given that soil carbon potential represents the largest 'uncertainty' in our accounts, research in this area must be a top priority to fulfil our commitments under the Kyoto Protocol.

Even if there was an on average loss of soil carbon this does not necessarily mean a blow out of our emissions for the Kyoto Protocol 2008 - 2012 commitment period. Rather the 1990 accounts would be recalculated to include an increase in emissions in this baseline year. So there would be little or no change to Australia's target for the first commitment period.

We must also measure our farm sources and sinks so that farmers can learn how to lower their emissions. If you can't measure it, you can't manage it.

Farming systems and carbon sequestration

The limited research to date has shown that under some farm management practice soil carbon decreases and under other practices soil carbon increase. Generally pastures tend to build up soil carbon more than cropping, with perennial pastures more effective than annual pastures (Table 1). Some cropping methods build up soil carbon whiles others reduce soil carbon.

Table 1; Increase in soil Carbon over 25y (1968-93) from 45 farmers sites in South Australia & western Victoria.

Practice	Tonnes Carbon /ha/year	Tonnes CO2e /ha/year	
Crop	-0.136	-0.50	(most lost C)
Annual Pasture	0.18	0.66	(most gained C)
Perennial Pasture	0.82	3.01	(all gained C)

(from J Skjemstad, CRC for Greenhouse Accounting)

The published literature on cropping practices shows a wide range of sequestration / emissions rates due to change in soil carbon levels (Valzano et al 2005). The affect of cropping on soil carbon depends mostly on the level of cultivation and the yield of total biomass (i.e. plant growth). Cultivation of the soil causes a loss of soil carbon, while minimum tillage tends to lead to increases, or at least maintenance, of soil carbon. Stubble management and fertiliser practices have a smaller affect on soil carbon. However the combined agronomic package will determine the biomass production of a crop and therefore has a significant affect. The affect of any particular management practise on soil carbon will depend on the soil type and the climate of a location.

Geoff Anderson, Department of Agriculture and Food WA (DAFWA) estimates the potential sequestration rates for no till cropping in the wheat belt of WA at between 0 to 6 t CO2e /ha/year depending on the soil type and rainfall zone (pers. com.).

The affect of plant nutrient supply is complicated. Plants source nutrients from both applied fertilisers and from the soil itself. An improvement in nutrient supply will lead to increased biomass production and therefore more carbon being added to the soil. However the source of the nutrients and type of fertiliser has a more complicated effect on distribution of carbon into the various carbon pools within the soils. Soil microbes convert fresh plant and animal material into organic compounds in the soil. These organic compounds will eventually be returned to the atmosphere as CO_2 gas.

Research is starting to emerge showing that soil biology may have a large affect on how much, and for how long, carbon is stored in the soil. Soil microbes take fresh plant and animal material and break it down into organic compounds. The microbes extract energy from the organic material and release CO_2 gas as a waste product of this 'respiration' process. A proportion of the consumed organic material can not be digested by the soil microbes and is released as waste organic matter. The waste from one microbe can become the feed stock for another. The chemical transformation of organic carbon in the soil is a complex web of microbial digestion. With each step there is a loss of some carbon back to the atmosphere as CO_2 and a transformation of remaining carbon to organic compounds that are progressively less degradable and longer lasting. Ultimately carbon in the soil will be converted into to stable 'humic' compounds that are not be degraded by soil organisms.

Humus can last in the soil for centuries and can be considered as permanently sequestered carbon for green house gas accounting purposes. One criticism of soil carbon sequestration (i.e. Article 3.4 sinks) is that soil carbon is short lived compared to the carbon in trees (Article 3.3 sinks). While a proportion of organic carbon in the soil does turn over very rapidly, soil humus will last far longer than any tree or wood derived products. The challenge is to find farming methods that convert the greatest proportion of carbon entering the soil into these very long lived soil carbon pools.

Research is just starting to address how farm management practices influence the soil biological processes that ultimately produce 'humus' in the soil. It appears that soil fungi called 'mycorrhiza' play a key role in converting fresh organic material into humus. Some farming systems appear to be much more capable of converting plant derived carbon to soil humus. Some farming systems encourage conditions that favour long lived mycorrhiza over bacteria and short lived mycorrhiza.

Factors that favour the long lived mycorrhiza are reduced tillage, permanent perennial plants and moderate amounts of readily available Phosphorus and Nitrogen. Reduced tillage and perennial pastures have widely been recognised as factors that increase soil carbon sequestration in long term trials. In the past having a permanent perennial pastures has meant that growing annual crops on those paddocks was not an option. However, recently a practise called 'pasture cropping' has developed where winter annual crops (e.g. wheat, barley, oats & cereal rye) are being grown over the top of summer active perennial grasses. The summer growing grasses are referred to as 'sub tropical' or 'C4' perennials. The sub tropical grasses are winter dormant and do not compete vigorously with the annual crops in winter.

'Pasture cropping' was pioneered by Colin Seis on his farm at Gulgong in NSW. Colin has developed the system to the point where the winter crops yield as well on his perennial grass paddocks as in paddocks without the perennials. In addition the 'pasture cropping' gives extra summer feed, year round soil protection and higher levels of soil carbon. Soil analysis from 'pasture cropping' paddocks at Colin Seis' farm, compared with conventional cropping paddocks over the fence are showing not only an increase in soil carbon, but also that a smaller percentage of soil carbon is in the short lived 'labile' carbon pool (figure 4&5).

'Pasture cropping' was tested for the first time at Geraldton, WA in 2007 with very encouraging results despite being a very dry year. It appears that this new carbon sequestering cropping system may have applications in many cropping districts.

Figure 4: Total soil organic carbon (t/ha) in adjoining paddocks under a) 'pasture cropping' where cereals are grown over the top of perennial grasses and b) 'conventional cropping' with a traditional pasture phases, at Gulgong NSW. (Colin Sies, Christine Jones and Van Bushby 2007, unpublished data)

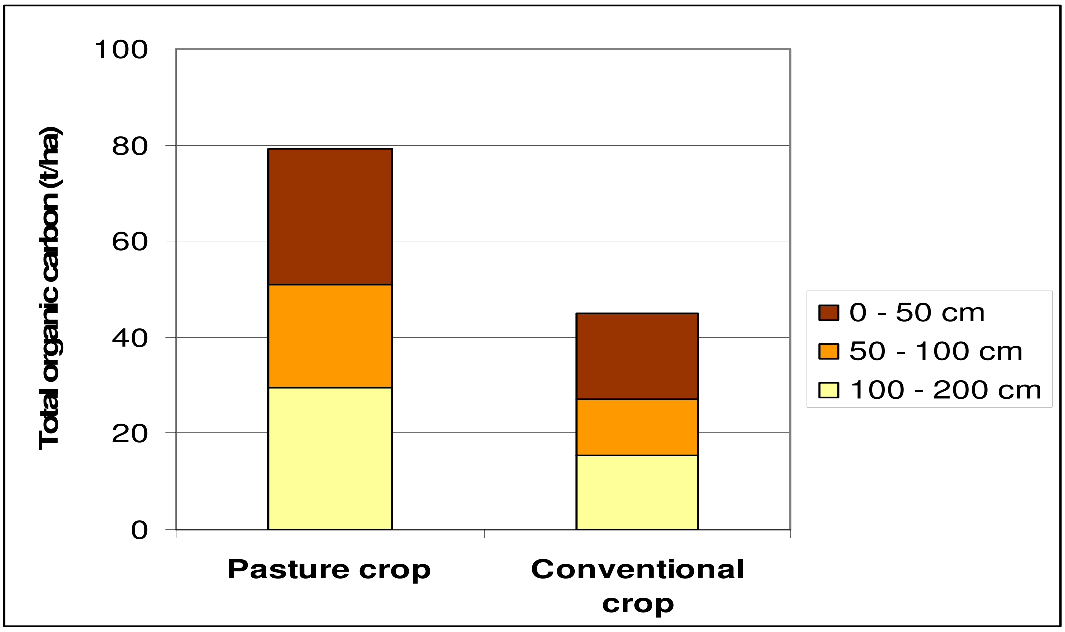
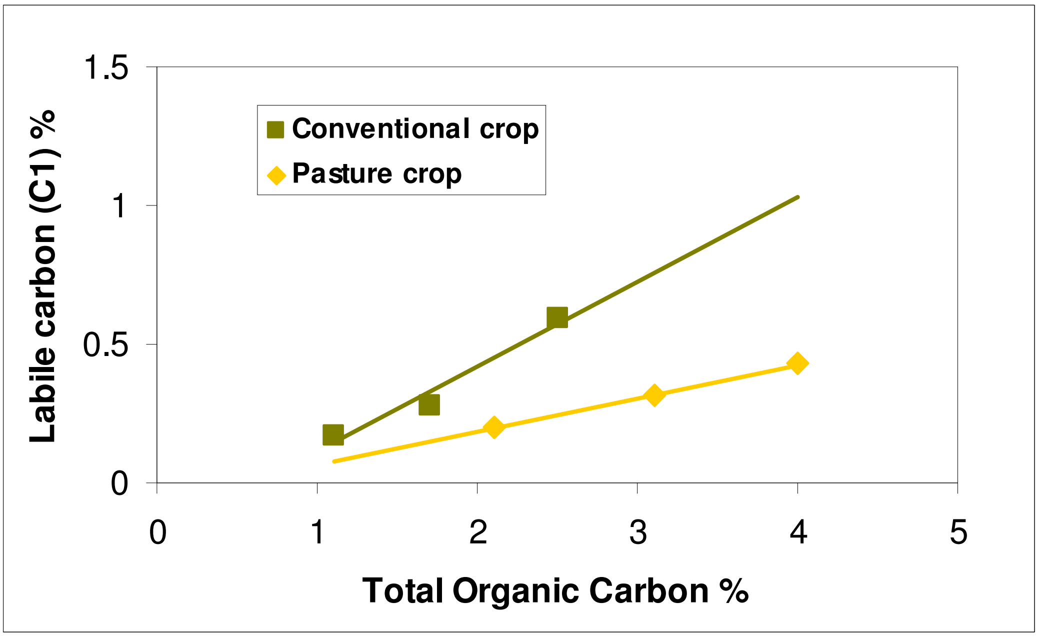


Figure 5: Labile soil organic carbon pool (%) compared to Total soil organic carbon (%) in adjoining paddocks under a) 'pasture cropping' where cereals are grown over the top of perennial grasses and b) 'conventional cropping' with an traditional pasture phases, at Gulgong NSW. (Colin Seis, Christine Jones and Van Bushby 2007, unpublished data)



Sequestration of crops and pastures versus trees

Sequestering carbon in trees and other woody vegetations (Article 3.3 sinks) is more readily accepted than sequestration in the soil under crops and pastures (Article 3.4 sinks). This view is based more on the fact that you can see trees but not soil carbon, rather than on the actual amount of carbon stored. Broad acre agriculture has the potential to sequester far more carbon than the agroforestry industries in Australia.

Valzano et al (2005) have conducted a review of long term trials in Australia where the soils have been sampled for soil carbon under a range of different management practices. This review shows differences in soil carbon due to farm management practices. Productive pastures had the highest levels of soil carbon. Generally cropping resulted in lower levels of soil carbon than grazing (except in some situations where pastures were heavily over grazed). With cropping, the more the soil was tilled the lower the soil carbon stocks. The review suggested that when cropping, changing from 'multiple cultivation' to 'one pass seeding' could increase soil carbon stocks by 25%. The Valzano review demonstrates that it is possible for farmers to impact on soil carbon stocks through their management decisions.

Given that there is about 23 million hectares of land cropped in Australia each year, changing to 'zero tillage' cropping could reduce Australia's emissions by 10's of millions of tonnes of CO2e each year. Changes in grazing practise would have an even bigger impact as a) potential sequestration rates are even higher than zero till cropping, and b) a far larger area of land is managed for grazing than cropping.

The Valzano et al (2005 review) found that productive pastures had higher levels of soil carbon than undisturbed wood lands. This finding challenges the widely held view that the only way to reduce emissions from agriculture is to plant farm land to trees. Other evidence is also emerging that broad acre tree planting may not be the best way to reduce Australia's emissions. Currently timber crops for lower rainfall (< 600 mm) farming regions are mostly not profitable (Harper et al 2007). However 'agroforestry' systems where trees and woody shrubs are integrated with cropping and/or grazing does have wide spread potential.

It is also widely assumed that the carbon in trees is stored for longer than the carbon in soils. However, trees don't last forever. They are either harvested or die natural deaths and the carbon sequestered is eventually released back to the atmosphere. Their effectiveness as a carbon sink depends on the rate at which they grow (i.e. sequestration) and the rate at which they decompose or are burnt (i.e. emission).

The growth rate of trees peaks early in the life of a plantation at less than 20 years of age. Old mature forests grow slowly and the growth rate is in balance with the decay / burning rate. The growth rates of timber plantations is maximised by regularly harvesting and replacing the trees.

The time that the carbon in the harvested products is stored depends on what the wood is used for. Paper has a life of less than 3 years while construction timber lasts for an average of 90 years (Richardson 2005). The average carbon storage life for timber products depends on the mix of products. Similarly the storage life of soil carbon varies depending on the mix of carbon pools. Some forms of soil organic carbon last less than a year while other pools last over a thousand years. Most of the carbon in the soil is in forms that last for longer periods of time than carbon stored in timber products.

Richardson (2005) compared the total net carbon sequestration for a Eucalypt plantation that was either harvested for timber or left unharvested (Table 2). He calculated that harvesting trees regularly gives higher rates of sequestration than leaving trees to stands, with the highest CO2 accumulation rate for a 16 to 20 year harvest cycle. Once taking into account the half life of the carbon in the harvested products there was little difference in the CO2 sequestered over a 100 year term. However there was substantial difference in the cost of sequestering each tonne of CO2 due to the sale of timber from the harvested plantations. Leaving plantations unharvested increased the cost of sequestering carbon by 3.6 fold.

Table 2; Cost effectiveness of sequestering carbon in timber plantations

	Unharvested	Harvested
Tonnes CO2 sequestered over 100 years	337	324
Net cost* per hectare	$6,526	$1,723
Net cost* per tonne CO2	$19.34	$5.32

* Net costs = Costs - Income

While having a price on carbon would improve the profitability of tree cropping, it would also make carbon sequestering grazing and cropping systems even more profitable relative to timber crops in medium and low rainfall regions.

If Australia's cap and trade scheme allowed timber crops under Kyoto Article 3.3 but excluded cropping and grazing sinks under Article 3.4, there could be the perverse outcome of a net increase in Australia's Green House Gas emissions.

Government policies relating to timber crops have already had negative affects on some regional economies and regional communities. Having tax concessions for commercial tree planting, but not for other forms of agriculture has had adverse outcomes for the high rainfall region of WA. Large areas of highly productive farm land have been converted to growing Tasmanian Blue gums. Farmers have signed long term contracts with timber companies despite the lease income per hectare being less than that from well managed grazing. This has occurred because leasing land requires no work for aging farmers and there is a secure income well into their retirement. The net effect of these tax minimisation schemes has been a contraction of the local economy, employment and community. This government policy has also had the adverse affect of diverting investment away from the enterprises that are potentially more sustainable in triple bottom line terms. The cap and trade scheme must be broad and unbiased to ensure market forces can deliver the optimum outcome.

It was also argued that favourable tax concessions for Tasmania Blue gums would help address land degradation from dry land salinity. However in WA the Tasmanian Blue gums have mostly been planted in very high rainfall areas where dry land salinity is not a problem.

A recently announced deal worth $100 million will see Woodside contract CO2 Australia to buy farms in the lower rainfall regions of NSW and WA to plant oil mallee which are Article 3.3 sinks. Article 3.4 sinks are not being considered because they are currently not acceptable as 'mandatory' offsets under the NSW Greenhouse Gas Abatement Scheme (a limited state based 'cap and trade' scheme). This is despite Woodside requiring the off sets for its Pilbara gas plant under WA laws and not NSW legislation. A mix of Article 3.3 and 3.4 sinks may give a better outcome for regions targeted by this deal.

Methane from livestock

Cattle, sheep and goats produce methane gas due to the digestion of the feed by microbes in the rumen (fore gut). This microbial digestion is referred to as 'enteric fermentation'. The methane from enteric fermentation accounts for 2/3 of the total green house gas emissions from agriculture in Australia. A simplistic view is a reduction of the numbers of livestock would result in a reduction of Australia's total GHG emissions. However changes in livestock farming methods could both increase Australia's meat production and at the same time reduce net emissions.

A recent report by the FAO called 'Livestock's long shadow' has recalculated the emissions from livestock and concluded that red meat animals account for 40% of all the worlds' emissions. Unfortunately this report ignores the GHG accounting methods ratified by the governments of the world under UNFCCC treaties. The Australian government should protest to the United Nations in the strongest possible terms that one of its organisations (i.e. FAO) would publish an official report that contradicts treaties signed by the member nations of the United Nations.

The 'Livestock's long shadow' report has totally ignored the accounting methodology laid out in the IPCC 'Guidelines for National Greenhouse Gas Inventories'. The report allocates emissions to livestock from the 'Land Use Change', 'Crop land', 'Transport', 'Industrial processes' and 'Stationery Energy' sectors. It then averages these emissions over all livestock in the world. The total emission includes large amounts of GHG from the clearing of forest in South America. It crudely assumes that all the cleared land is used for cattle production.

The report also includes emission due to growing grain for feed lotting animals in North America and Europe. In these cold climates livestock must be kept in doors and hand fed during the very cold winters. In Australia cattle and sheep spend most of their life grazing directly from pastures which are likely to be sequestering carbon.

The FAO report also conveniently ignores the reduction of emissions in Australia due to bans on clearing regrowth on grazing land in Queensland and NSW.

Unfortunately there are not yet accurate whole farm audits of green house gas emissions and sequestration under Australian conditions. Estimates of methane emissions can be made relatively easily and with reasonable confidence based on the number and class of animals on a property. How much of the methane emissions may be off sets by carbon sequestration in the soil and vegetation of the grazed land is much more difficult to assess.

An attempt has been made to do a full Green House Gas audit for two farms using perennial pastures and fodder shrubs in innovative ways. Colin Seis 'pasture crops' over his native perennial grasses in a one in four year cropping rotation. Colin also uses an intense rotational grazing system (Holistic management). An audit of Colin Seis's was calculated based on the whole farm production.

Bob Wilson at Lancelin in WA has a grazing only farm. Half his farm (i.e. 1,000 ha) is established to the fodder shrub tagasaste. Bob is now in the process of replacing the other annual pastures with sub tropical grasses. A full carbon audit was conducted on a per hectare basis for the tagasaste and perennial grass paddocks.

Changes in soil carbon pools have been estimated for these farms using paired paddock soil sampling. For the tagasaste paddocks estimates of the carbon build up in the wood and roots was based on direct measurements of the carbon in tagasaste from another trial site. The emissions of methane were estimated from number and class of livestock.

A web based model was used to estimate other CO2 emissions from fuel and chemical use for both farms. The net carbon emission / sequestration were then divided by the produce sold off the farm to calculate the true foot print of their farm produce. The results of the calculations are given below

Colin Seis, Gulgong, NSW
Native perennial grass, rotational grazing, 'pasture cropping' over native grasses 1 year in 4.

Carbon balance for whole farm	**CO2eq**	
Sequestration - Increase in soil organic carbon	-7,200 t	based on comparative soil sampling over the fence with brother using a traditional grazing systems with sheep on native perennials with occasional full cut cropping
Total farm emissions	2,200 t	based on a whole farm audit using a web based calculator
Net sequestration	**-5,000 t**	

Produce sold off farm	
Animal live weight	50 t
Wool	20 t
Grain	100 t
Total	**170 t**

It is not possible to allocate the net sequestration and emission between the different farm products, so an analysis is done on the combined farm 'produce'.

CO2eq per kilogram of product sold = net emissions / total produce sold

29 kg CO2eq / kg of product sold (5,000 t CO2eq / 170 t product)

Bob Wilson, Lancelin, WA
Beef production from tagasaste (1,000 ha), perennial grasses (200 ha) and annual pasture (800 ha)

Carbon balance for perennial & tag paddocks	**CO2eq**	
Sequestration - Increase in soil organic carbon	- 7.7 t/ha	based on comparing soil samples in adjoining paddocks of perennial grass & tagasaste compared with the traditional annual pasture
Paddock methane emissions	0.7 t/ha	extra methane emissions from extra stock on perennial and tagasaste paddocks
Other farm emissions	2.0 t/ha	ball park estimate
Net sequestration	**- 5 t/ha**	

Produce sold off farm	
Animal live weight	0.2 t/ha
Total	**0.2 t/ha**

CO2eq per kilogram of product sold = net emissions / total produce sold

25 kg CO2eq / kg of product sold (5 t CO2eq / 0.2 t product)

Both the 'pasture cropping', and the tagasaste / perennial grass grazing systems were calculated to be net sequesters of carbon. Consumption of food produced from these two farms would help to reduce the global warm problem, rather than contributing to it as now being widely promoted in the public arena. Further the value of the carbon sequestered for each kilogram of meat consumed can be calculated from Bob Wilson's farm as it only produces beef.

<u>Sequestration per kilogram of meat from Bob Wilson's</u>

CO2eq Kg per Kg live weight	= 25
Meat yield per Kg live weight	= 50%
CO2eq Kg per Kg meat	= 50
Assumed CO2 price $ / t	= $20
Value of sequestration per Kg meat	=$1.00

While these calculations are crude (but unfortunately the best currently available), they indicate that meat production under appropriate methods could be a critical part of the cure for global warming rather than the cause.

Agricultural research required on carbon sequestration

Valzano et al (2005) reviewed all of the Australian research that has been published in scientific journals. Only 50 papers had sufficient data to do a complete calculation of the Total Carbon stocks in the top 30 cm of the soil. Of these papers 79% came from NSW and Queensland with only 21% from the rest of Australia. Of the papers reviewed, 88% were published prior to 2000. With most of these being long term trials, the initial farming methods investigated were selected decades ago. These methods would not be representative of conservation cropping systems widely used in Australia today. The research reviewed certainly does not include more recent innovations which are being developed and adopted today such as 'pasture cropping', intensive rotational grazing, fodder shrubs and sub tropical perennial pastures in temperate environments. The limited range of the trials in the review indicates that there is a serious deficiency in the research effort on soil carbon sequestration in

Australia. While agriculture could play a very large role in reducing Australia's GHG emissions there is a need for very significant investments into long term farming trials on 'crop land' and 'grass land' carbon sequestration.

To improve the accuracy of Australia's Nation Carbon Accounts research is required on…..

e) Nett sequestration/emission rates for the major farming method for each region
f) The area of each farming method for each region

Specific research is required for soil or vegetation carbon sequestration to be traded as green house gas off sets. To support trading research is required on…..

g) The most cost effective farming methods to sequester carbon in broad acre agriculture
h) Cost effective methods for measuring, accrediting and auditing net carbon sequestration

Funding for Research & Development

For a comprehensive coverage of Australian agriculture a major research effort is required. While government will need to play a central role in that research effort, it may not have to cover the entire cost.

Self funded research
If carbon credits were sold from farm land they would in one sense be just another farm commodity. Currently all the major farm commodities have a 'research levy' collected when farmers sell their produce. In the same way a research levy could be collected from the sale of carbon credits to cover the research required to support the carbon commodity. Though to get carbon trading for agriculture going, 'start up' funding would be required.

The size of this carbon levy pool could be considerable. If we assume an average

- 0.5 t CO2e/ha/year were sold as off sets (i.e. 136 kg C/ha/year),
- a 2% levy on a sale price of $20 /t,
- 235 million hectares of agriculture land (i.e. 50% of potential land),

would mean there would be $47 million per year available for research.

Government research
Considerable progress on research could be made by broadening the scope of existing research projects to included measurements of carbon sinks and sources. A wide range of existing agricultural research could generate much information with minor modifications to experimental design and some extra resources for measuring carbon. Government funded research organisations could make it a key priority to collect data on green house gasses from existing experiments. The Federal government should supply the additional funds to support this activity as it will be a direct financial benefactor of the resulting reductions in the Agriculture sectors reductions in net emissions under the inter-national 'cap and trade' system of the Kyoto Protocol. Any reduction in the Agriculture sector emissions lowers the total national emissions and therefore Australia's liability to meet its 'cap' under the Kyoto Protocol.

Private enterprise research

Private industry may also be a major source of funds for research on carbon sequestration in agriculture. Major mineral and energy resources companies are already investing, or considering investing, in carbon farming research.

Currently one mining company in the Geraldton region of WA is funding a scoping study for a major carbon farming research project in the region. They have several objectives that this project could contribute to. Firstly, like many other large companies they are accepting their responsibility to reduce the emissions from their business. As their operations expands so will their emissions and the need for carbon off sets. Carbon farming systems in the local region could supply the offsets the company will need in the future. The company also requires workers for its mine which is just inland of the northern wheat belt. The miners see local farmers as supplying a pool of labour who wish to live in this isolated region.

This particular region is already suffering the affects of climate change with 8 consecutive years of below average rainfall. It now appears that the traditional wheat growing enterprises may not be viable due to climate change. Agriculture in some of these districts could collapse unless new farming methods are developed. New farming systems are required that will keep the farms viable so that local communities are maintained as well as a pool of local workers are available for the mining industry. The company is therefore prepared to spend substantial funds to test and develop innovative farming systems that produce carbon off sets, are productive and are economically sustainable so that people remain in the region.

This mining company owns three farms as a consequence of their planned operations. These farms will be used to test a wide range of both traditional and emerging farming methods. The experiments will be both at the small plot scale and at the paddock scale. Data will be collected on crop production, animal production, economics, dry matter production and carbon pools. The information will be used to calculate the net carbon sequestration rates and traditional yields so a complete farming systems audit can be undertaken, including carbon trading. The results will be extended to farmers, advisers and government agencies to guide the restructuring of agriculture in this low rainfall region.

Measurements of changes in carbon pools will use the detailed protocols out lined by the Australian Greenhouse Office. The data will be gathered so that the RothC model can be refined and validated for the region. Once RothC is calibrated much simpler methods can then be used to measure changes in carbon pools and sell carbon off sets at a commercially viable cost. A calibrated RothC model can then also be used to reduce the uncertainty of Australia's National Carbon Accounts.

The negotiation on this large research project have not yet been finalised, but some funds have been allocated for the project development and baseline carbon testing. Other miners in the Geraldton region have also expressed an interest to invest in this type of research but discussions are at a more preliminary stage. Two large corporate farmers are also interested in paddocks scale research on sequestration.

Big business is interested in investing in medium and low rainfall agriculture regions, and the rangelands, although there is some reluctance to commit until the details of Australia's domestic 'cap & trade' scheme are known. Key questions are whether agriculture will be included in the 'trade', and specifically if Article 3.4 sinks will be included. If the off sets from 'crop land' and 'grass land' are not tradable then big businesses won't invest in research for the lower rainfall regions that cover the bulk of Australia.

Farmer research
Farmers are likely to be the largest source of data for research. Farmers currently collect and analyse soil samples for a range of factors including carbon. Over 100,000 soil samples are tested each year through commercial laboratories in WA alone. The sampling methods used by farmers are aimed at helping them determine their fertiliser requirements. Farmers monitoring paddocks over time can get an estimate of the net sequestration rate of the management used in individual paddocks, but with fairly high level of uncertainty.

The farmers sampling methods do provide some useful information on soil carbon, but not to the level required for an accurate assessment of carbon sequestration / emission. Farmers do not collect data on Bulk Density required to calculate the tonnes of carbon on the soil (i.e. only the % carbon). Also farmers usually do not GPS the sampling sites so that samples are not taken from exactly the same spot each year. Soils are usually analysed for 'Organic carbon' (Walkley Black method), but this can reliably be converted to 'Total carbon' once the conversion factor for the soil is known.

There is a trend for farmers to use contractors with coring rigs to collect their soil samples. It should be possible to have sampling contractors accredited to use standardised sampling protocols that would give a reliable estimate of soil carbon pools. With coring machines it should also be possible to estimate Bulk Density from the samples collected (with calibration against direct measurements). Commercial labs could also be accredited to use standard analysis procedures.

For a complete account of carbon pools an estimate of the amount of carbon in the various vegetation is also required. Remote sensing technology using satellites has already been commercialised for measuring the amount of dry matter in annual pasture paddocks (i.e. 'Pastures from space'). New satellites are being launched with instruments such as NIR that have the capacity to discriminate between vegetation types. These emerging technologies will improve the capacity for remote sensing of vast areas of land at low cost. Further investment by government will be needed to develop these tools and take advantage of new technologies as they emerge.

The farmer's soil data could be added to a centralised data bank for Australia. With some additional paddock information collected, there would be sequestration rate data for a huge number of sites in Australia. This would allow a very accurate assessment of changes in Australia's agriculture carbon pools. The data could also be used for the calibration models such as RothC.

The farmer soil samples combined with remote sensing and RothC type models would become the basis for farmers trading carbon off sets. This direct financial return would be the incentive for a large increase in the soil sampling by Australian farmers. Ultimately if farmers were required to do a full net carbon accounting then some soil testing to verify their accounts would need to become compulsory.

National coordination of Research

A coordinated approach is required into research and development on Green House Gas issues for Australia. There must be standardised approaches to data collection, analysis and modelling so as to:

c) allow Australia to use a Tier 2 or Tier 3 assessment of 'Agriculture' net emissions
d) develop national standards for measuring, selling and auditing off sets from agricultural land.

Carbon pool models such as RothC are essential to underpin our National Carbon Accounts and for the trade of off sets. Direct measurements of carbon pools will never be viable at the scale required. Models allow simpler measurements to be used to estimate changes in carbon pools. These models are empirical and their accuracy depends on the volume and quality of data used in their construction.

International R&D aid

The UNFCCC convention requires developed nations to give assistance to developing nations so that they can reduce their green house gas emissions. Australia and New Zealand are the only two developed nations were agriculture is a significant contributor to green house gas emissions. We could become world leaders in turning farm land in to a net sink through the trading of Article 3.4 sinks. By sharing our technical knowledge and trading system with developing nations we would meet our commitment to help developing countries have a greater impact on mitigating global climate change.

Adaption opportunities to agriculture and forestry

A range of farming technologies are being developed and adopted in the Northern Ag Region of WA that can adapt to lower and more variable rainfall. Eight years of below average rainfall and two of extreme drought have clearly identified those farming systems that can performed under the climate change predicted for southern Australia. The new farming systems that are being developed and successful tested by farmers in this region are listed in Appendix 1, and a case study in Appendix 3.

These innovations have emerged from both researcher's trial plots and farmers paddock trials. Farmers, local agribusiness and local researchers have collaborated closely in the development and testing of these innovations. Local farmer groups are playing an increasingly active role in the extension of these innovations. Demonstration of these innovations at the paddock scale by the pioneering farmers has been the most successful method for convincing other farmers to adopt these new systems.

The Evergreen Farming Group was specifically set up in 2000 to empower farmers in the research and extension of perennial pasture systems. The Evergreen group collaborates with researchers from a number of WA agriculture research organisations and with other farmer groups in WA. It now has 500 members in WA and a small but growing number in the east. The Evergreen group works in partnership with other farmer groups in WA to ensure engagement with a large number of farmers.

How might these adaption challenges be addressed?

Innovation by definition means change. Change also by necessity means increased risk. As rational decision makers farmers tend to avoid, or at least minimise risk. One way to minimise risk with change is to take small incremental steps. In this way new systems evolved slowly over time without the possibility of large losses at any stage. Unfortunately this 'evolutionary' path is not adequate when large and sudden changes in the operating environment render the traditional methods unviable. In such case 'revolution', rather than evolution, is required. In this case large radical change may carry less risk than the small incremental changes which can not produce viable new systems in the time required to avoid disaster.

The Northern Ag Region of WA has been a leader in innovative agriculture as a result of having to minimise risk. The main risk that the innovative farmers have had to deal with is the immanent failure of their traditional farming systems.

The first radical new farming system developed on the coastal sand plain north of Perth was the fodder shrub 'tagasaste'. This region contains large areas of deep, coarse white sand which are the world's least fertile farm land. The region was not opened for agriculture until the 1960's. The early annual crops and pastures imported from the adjacent wheat belt where not suitable for the poor white sands. By the early 1980's farms on the sand plain where is serious economic and environmental decline. In 1986 the first sand plain farms were abandoned. Fortunately John Cook at Dandaragan had planted 2 hectares of tagasaste in 1982. To almost every ones surprise his tagasaste survived and grew. While the experts remained sceptical, the locals facing disaster were desperate for an alternative. For them the risks from doing nothing were absolute and inevitable. For the pioneers it was never a question of whether tagasaste could be made to work, but rather simply a case that it had to.

The early development was done by a hand full of farmers with very limited resource. While they did make progress it would have been too slow for them to remain in business until tagasaste was developed to a commercially viable stage. Fortunately one local farmer, Sir James McCusker, was also a banker who had just retired and sold his business. He invested $2,000,000 over 8 years to fast track the development of tagasaste. His 'Martindale Research Foundation' not only employed researchers but actively encouraged the participation of the pioneering farmers in the research. The year after 250 farmers attended a field day at Sir James' 'Dunmar' farm, the area of tagasaste in the region double from 20,000 ha to 40,000 ha.

The key ingredients for a revolution in farming methods are

a) the threat of immanent failure,
b) pioneering farmers,
c) dedicated researchers,
d) collaborative R&D and
e) substantial funds for an intensive period of R&D.

It now appears that a climate shift occurred in the northern wheat belt of WA in 2000. The global warming theory predicts steady changes in weather patterns until a new equilibrium is reached, and then there is an abrupt and permanent change to a new weather pattern. Traditional statistical methods unfortunately require large amounts of data. With climate change this means long periods of time before a change in climate can be confirmed 'statistically'. The statistical methods of Denning (i.e. Total Quality Control) allow the detection of change in a process much more rapidly. One of Denning's rules is that '7 consecutive events either above, or below, the average means the average has changed'.

The evidence shows that there had been a gradual decline in rainfall in southern WA between 1970 and 2000 of about 1 to 2 mm a year. Both wheat yields and farm profit in the northern wheat belt actually increased during this period. This is because of the evolution of cropping technology has delivered a 3% to 4% yield increase per year. Since 1999 there have been 8 consecutive years of below average rainfall in the Northern Ag Region. This could be due purely to chance, but the odds are the same of throwing 8 heads in a row. Rainfall for the decade is 25% below the long term average for Lynton in the Northampton shire (Figure 6), with 17 of the last 20 years having below average rainfall (Figure 7). Modelling by the CSIRO had predicted that the rainfall in this region would fall by 30% by 2050. It appears that this reduction in rainfall may have almost occurred already. Unfortunately the 4th Assessment Report of the IPCC is showing that the measured changes in the world's climate have been at or above the worst case predicted by the global climate models.

It appears that we do not have the luxury of time to adapt to climate change in an evolutionary way. Radical changes are required, but these inevitably incite scepticism from 'experts'. Experts have influence on research funders, and they can prevent the funding of true innovation.

An expert is a person who will proclaim that a new idea will not work even before it has be tested, or worst still simply because the expert has not tried it themself.

Figure 6; Total yearly rainfall for Lynton, Northampton shire which is in the north part of the Northern Ag Region of WA.

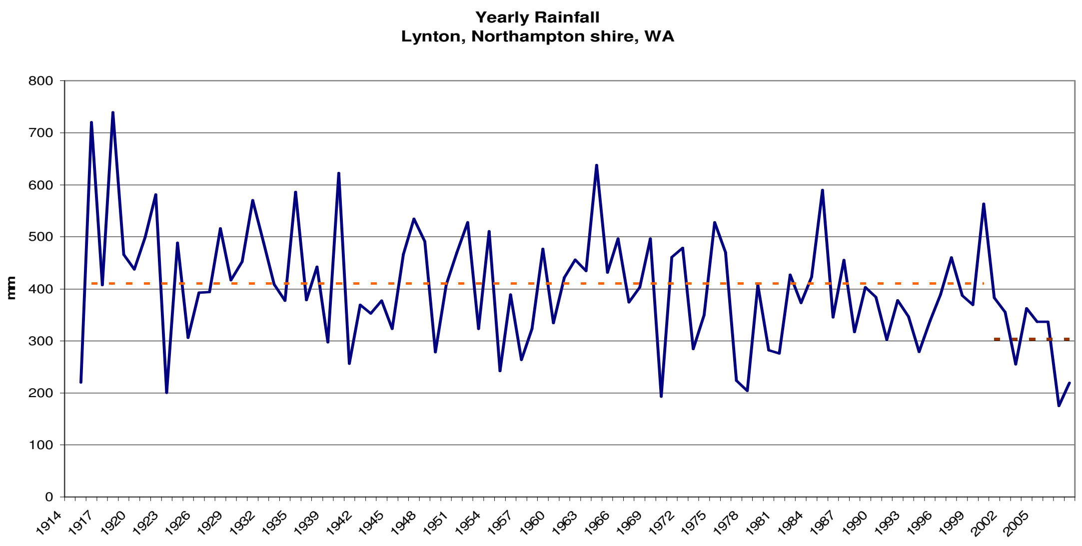
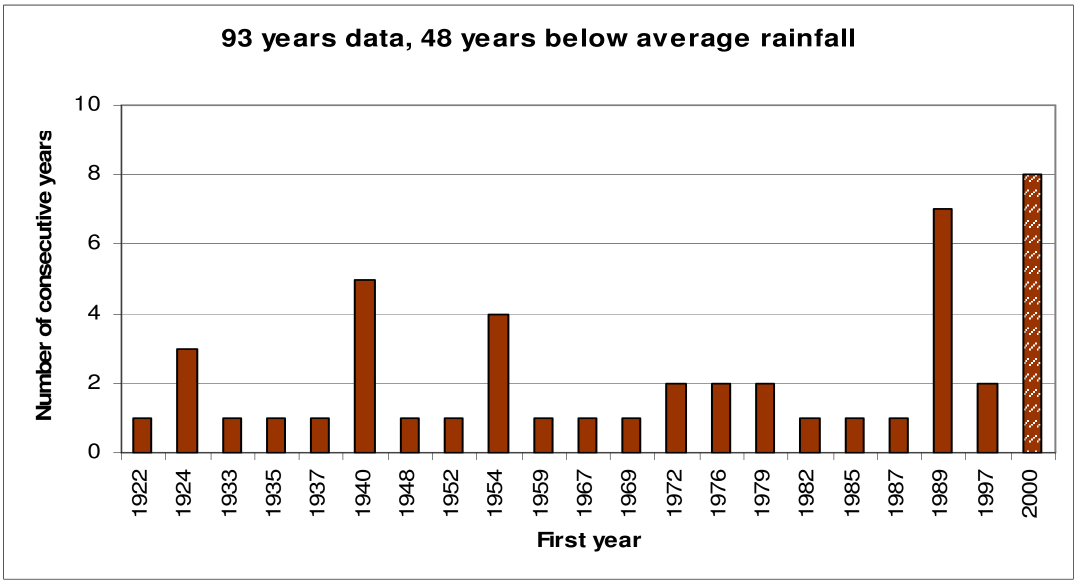


Figure 7; Number of consecutive years of below average rainfall at Lynton, Northampton Shire, WA.



Marketing Article 3.4 sinks

Currently Article 3.3 sinks are being marketed through the NSW Greenhouse Gas Abatement Scheme. Article 3.3 sinks include woody vegetation that is greater than 2 meters tall and more than 20% crown cover. These tree and agroforestry options are easy to see and thus confirming the land use practice. Estimates of the tonnes of CO2e stores can be made from indirect, but simple to gather measurements (e.g. breast height trunk diameter and tree density).

There are a number of challenges to marketing Article 3.4 soil and vegetation carbon sinks from broad acre agriculture. These challenges included

a) Cost effective measurement methods
b) Uncertainty of the estimate
c) Verification of carbon credits over time
d) Potential for farmers to change their management practices
e) Sequestration rates vary over time and with changed management
f) Non permanence of carbon in soils and vegetation
g) Length of time for the contract of carbon storage
h) Financial instruments for marketing carbon off sets

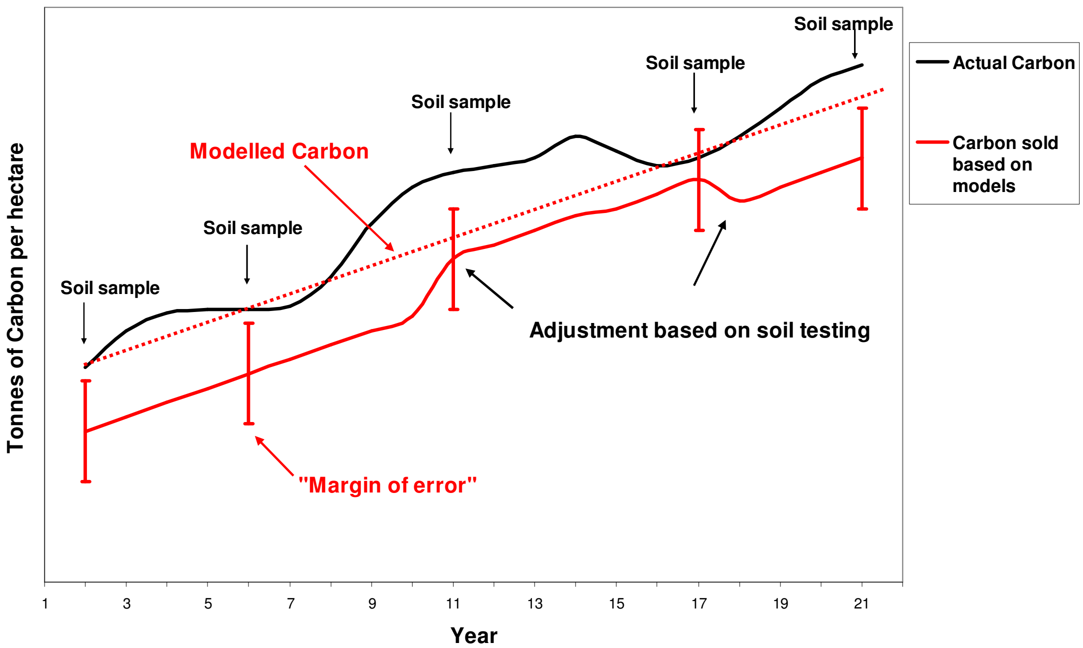
Measurement methods and uncertainty
Direct measurements of changes in soil and vegetation carbon pools using scientific methods will be too expensive for commercial trading of carbon credits. Carbon can be estimated at lower cost by using indirect methods that are calibrated and validated at research sites using detailed methodologies.

The simplest approach to estimating sequestration rates is to base it on farming practices. This approach is being used to sell soil carbon off sets through the Chicago Climate Exchange (CCX). Farmers are paid for contracting to use specific farm practice on a specific parcel of land for a fixed contract period. Acceptable farm practices are zero till cropping and improved pasture. The contract period may be for as little as four years. The rate of sequestration is estimated from the findings of a series of long term trials in the region. As there can be considerable variation between the actual trial sites and a specific farmer's paddock, farmers are only paid for a proportion of the estimated sequestration rate. There is a large margin of error used as there is considerable 'uncertainty' from a) extrapolating from the research sites to farmers paddocks and b) a lack of soil testing to verify that the soil carbon in the contracted paddock has actually increased at the rate predicted.

Scientists would struggle to accept the large experimental 'error' of the estimates used in the CCX scheme. However business can, and must deal will large uncertainties. Businesses deal with uncertainty by adjusting prices for 'risks'. In a mature and open market 'risk' discounts are built in to trade prices. The key for business is a realistic estimate of the size of the risk when they make purchases. The IPCC requires that all estimates of Green House Gas emissions and sinks come with a statistical measure of the 'uncertainty' or 'error' of the data. Article 3.4 sinks could also be sold with an estimate of the measurement error. The size of the error would then become an indicator of the quality of the carbon off set being sold. Or a 'margin of error' could be subtracted from the tonnes of carbon being sold, with the margin based on the statistical error of the estimate.

Estimates of carbon sequestration based on farm practices will always have a high degree of uncertainty. Direct measurement will be the most reliable indicator of sequestration, but will be too expensive for commercial trading. A trading system based on carbon pool models should reduce the estimate uncertainty and be cost effective. The risk from models would be reduced by periodic direct measurements of the carbon in the paddocks marketed. The data from paddock sampling could be then fed back to refine the models. This iterative approach would progressively reduce the uncertainty over time.

Figure 8; A model for trading Article 3.4 sinks ('crop land' and 'grass land') in an Australian 'cap and trade' scheme.



It is recommended that Article 3.4 sinks should be allowed to be traded in an Australia domestic 'cap and trade' scheme using a combination of

1. **modelled changes in carbon pools**
2. **a 'margin of error' discount based on the uncertainty of the estimate**
3. **adjustment of the tonnes sold based on periodic soil testing**

Full farm Green House Gas accounting
It would not be possible at this time to trade farm carbon based on a full farm audit of net Green House Gas sequestration / emissions. On-line programs are currently available for farmers to estimate the net farm Green House Gas emissions. However these models are crude and only account for limited detail. It will take considerable time and effort to develop the accounting systems for a full farm carbon audit. A national farm business carbon auditing system should be incorporated into taxation accounting systems.

An optional scheme could be developed fairly quickly for farmers to register and sell gross carbon sequestration in soil, vegetation and agroforestry. There would likely be a rapid uptake of this by farmers as it offers the potential for new income. This would allow the measurement, accounting and regulatory systems to evolve over a period of time in preparation of a mandatory scheme involving full farm carbon accounting.

Currently the NSW Greenhouse Gas Abatement Scheme trades gross sinks from tree plantations as they do not account for the emissions due to planting, managing or harvesting the trees.

Much of the data required to estimate emissions from fossil fuel consumption is already included in farmer's normal business accounts. However additional information would be required for emissions from livestock and other farm sources (e.g. fertiliser and chemical use, manure emissions). With the national Electronic Livestock Identification System (ELIS) there is now a very accurate data bank on cattle in Australia. No other country has a scheme like ELIS for monitoring livestock numbers and class. There are proposals to extend the ELIS scheme to all major classes of livestock. Once these are developed this data base could be linked to the auditor of farm carbon emissions.

It is recommended that Article 3.4 sinks be initially traded as gross carbon sequestration in the soil and vegetation until there is enough data and accounting systems in place to move to a net sequestration based on a full farm business carbon audit.

The non permanent nature of soil and vegetation carbon
Carbon credits from forests are being sold under schemes where the carbon is contracted to be stored for periods of time of around 100 years. These long term contracts are viable for tree plantations as these are long rotation crops. Carbon contracts that fix management practice for broad acre cropping or grazing for such long periods would not be feasible for farmers and graziers.

Marketing mechanisms are needed to deal with variability in the amount of carbon in soil and vegetation on crop and pasture land over time. Feng et al (2000) consider several options for dealing with variability of soil carbon.
These include a…..
Pay As You Go (PAYG) scheme where farmers where paid as if the sequestration was permanent, but would have to buy back carbon credits if the levels in the paddock fell below that which had already been sold.
Variable Length Contract (VLC) scheme where a broker would pool and sell carbon credits from a range of sources. An individual farmer would be contracted to store a given amount of carbon for a given amount of time. A farmer may not choose to renew the contract for storing carbon, but the carbon credits sold by the pool would be covered by new contracts with other farmers or by buying credits back in the open market. The price paid for a short term contract would be a portion of a given long term period such as 100 years (I.e. a 5 year contract would be paid at 5% of full market price).
Carbon Annuity Account (CAA) scheme where the farmers are paid the full price but the money goes into an annuity account as the principle. The farmer can then access the earnings of the account but not the principle. If the carbon stored falls then the principle would be used to buy carbon credits to off set the decline in the carbon stored in the paddock.

Any or all of these schemes can deal with variability of carbon pools. They allow the farmer to retain the flexibility to change his farming system in response to a range of economic and environmental signals. Farmers are unlikely to sign up to schemes that lock in their management decisions for long periods of time.

It is not necessary to choose just one of these marketing schemes for Australia's domestic 'cap and trade'. Rather it would be better to allow the financial industries to develop a range of schemes which farmers can choose between. Farmers can then choose the scheme that best suits their individual situation.

Carbon credits from farms will need to be sold through pools for all but the largest farm business. Aggregating credits will reduce the administrative and legal costs from the transactions. Pooling reduces the risks from unforseen losses of carbon on any individual farm.

The financial institutions could also offer marketing options that provide up front payments to finance changes to a farmers systems. With a Pay As You Go scheme the early payments are minimal but build up considerably over time. Some new 'carbon farming' methods can have large up front costs that are prohibitive for cash strapped farmers. Preliminary analysis of oil mallees in the low rainfall wheat belt of WA has shown it may only be economically viable if there is an up front payment sufficient to cover the cost of planting the mallees (C Peek and M Abrahams, DAFWA, Geraldton pers. com.). A local mining company has indicated that it would be prepared to provide the funds for farmers to implement carbon farming systems such as oil mallees, as long as they can secure the long term carbon rights.

The financial industry will have a key role to play in facilitating the uptake of agricultural carbon trading and financing the changes required to make agriculture a net sink of Green House Gasses.

The allocations of a 'cap' of carbon emissions for individual farm business

Under a full farm carbon auditing scheme farmers would not be required to off set all of their emissions. Under a 'cap and trade' scheme each business is given a 'cap' or quota of an amount of green house gas they can emit before being fined or having to buy off sets. Over time the 'cap' for each business is gradually reduce so that the total emissions of the sector and country falls. A key decision for any cap and trade scheme is working out how the cap is distributed between industries and businesses.

The two main methods considered for allocating caps are…

a) 'Grandfathering' where caps are given free to businesses based on their past level of emissions
b) Auctioning of the caps where market forces dictate the allocation between business and sectors.

One of the problems with Grandfathering is that existing businesses have an unfair advantage over business that may start in the future and won't get a free allocation of emissions. However the amount of land is fixed so that the allocation of emission quotas to existing farms based on the area of land does not restrict the expansion of agriculture.

A fully open emission auction scheme may have an adverse outcome in the allocation of 'caps' to farming businesses. Many cash strapped smaller farmers may not be able to compete in the market place. Even a closed auction within the farm sectors could see corporate farmers acquiring very large caps which could then be used to dominate and distort the farming sector.

It is recommended that the allocation of emission quotas to agricultural businesses be determined centrally by government rather than by auction.

The allocation by government should be based on a formula accounting for area farmed, rainfall / region and land use class (e.g. free hold vs. lease hold)

The total cap allocated to the agricultural sector should be considered in relation to the nation wide strategy for reducing green house emissions. Simply allocating to the sector based on the current estimates of Agricultures national emissions could be risky due to the large uncertainties due to Article 3.4 sinks. An attempt should be made to estimate the real emissions / sinks from 'crop land' and 'grass land', rather than relying on the 'Tier 1' assumption of no net change, so that a quota can be reserved for when farm businesses are included in full net carbon accounting.

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Leasehold land

For carbon credits from farm land to be traded there is the need for legislation to validate the ownership of the carbon sequestered. Under the constitution the state governments have primary responsibly for the administration of land. In anticipation of carbon trading the state governments have implemented acts that allow a 'carbon right' to be registered against the title of the land.

The Western Australia government has introduced the "The *Carbon Rights Act 2003"* which….
"provides for the creation of certain interests in land in relation to the effects of carbon sequestration from, and carbon release to, the atmosphere."

"Carbon rights are the combination of the rights arising from the storage of carbon in, and the risks associated with the release of carbon from, plants or soil as a result of changes to land management practices.
Carbon Rights legislation will create a new right in land that will be registered on the certificate of title to the land. This right, which can apply to either freehold or Crown land, will remain on the title until such time as it is surrendered.
The Carbon Rights in Crown land will remain owned by the Crown unless transferred to another person."

This act gives certainty to the ownership of carbon sequestered for freehold land owners but not for lease holders, such as pastoralists, in WA. The opinion of one WA State Minister is that pastoralists do not own the carbon on their lease. Therefore there would be no incentive for pastoralists to change their management to increase carbon sequestration.

The legal issues surrounding carbon in the soil have not yet been clarified adequately. In one sense carbon is a mineral that has a commercial value. But with agricultural sequestration it is being put back into the soil rather than being extracted as when mining. This 'reverse mining' was never considered when mineral ownership legislations were developed.

Each state has its own laws relating to leasehold land. WA laws only allow grazing on pastoral leases while other states allow cropping as well as grazing.

There is a need for a uniform approach by the states to the ownership of carbon sequestered on leasehold land due to the management actions of the lease holder.

Evan and Robin Pensini at Cheela Plains stations are showing what is possible in terms of carbon sequestration and sustainable grazing production using a new approach to station management. They have significantly intensified their grazing management on the 20% of their property that has the best soils. The other 80% has been mostly destocked, and is used only as a drought reserve. Under this management the vegetation cover, biodiversity and the soil are improving on both the lower quality degraded land and on the prime grazing country. They have actually increased the carrying capacity of the whole station while improving the natural assets at the same time. There has been considerable cost for the fencing and stock water infrastructure to set up their new management system. A reward for increasing carbon sinks would be an incentive for other pastoralist to invest in this far more sustainable system for managing the rangelands.

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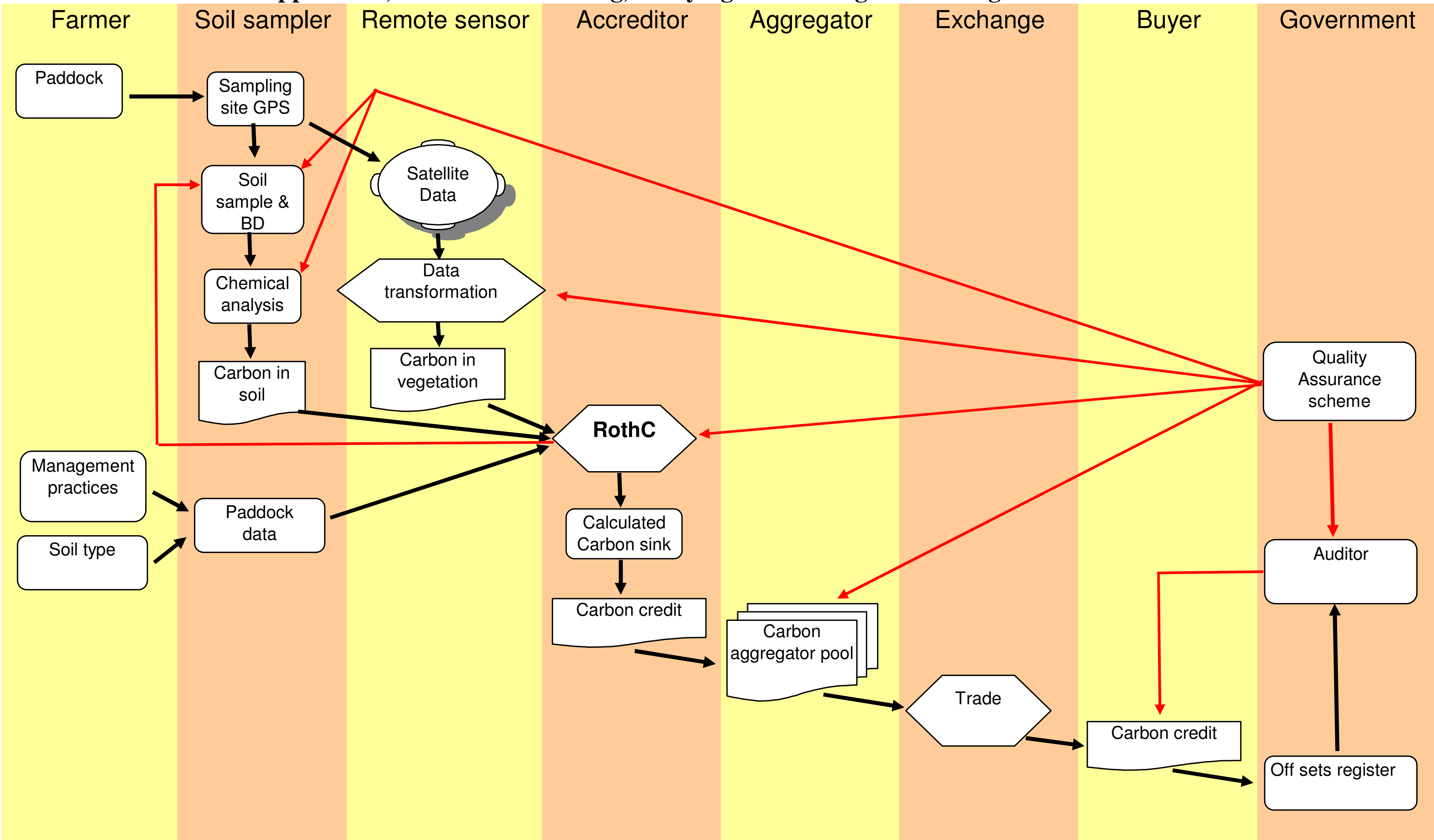
Appendix 1; New farming systems with demonstrated drought tolerance in the Northern Ag Region of WA.

Old system	New system	Examples	Adaption mechanism and benefits
Annual pastures	Sub tropical grasses	Green panic, Rhodes grass, a range of other C4 species	Biochemical drought tolerance due to C4 rather than C3 photosynthesis Deep roots (e.g. > 4.5 m on deep sands)
	Subtropical legumes	Siratro, Lotononis	Deep roots Biochemical (C4) drought tolerance in Siratro
	Fodder shrubs	Tagasaste, salt bush on none saline soils, Rhagodia (native shrub)	Extremely deep rooted (> 10m) Hydraulic lift Physiological adaptations
	Grazing cereals	Wheat, Oats, Barley, Cereal rye	Greater vigour and density than volunteer annual pastures More ground cover and reduced erosion
	Native herbs	Mulla mulla	Deep roots Other unknown adaptation's to drought
Set Stocking	Intensive rotational grazing	'Holistic management' 'Grazing for profit'	Better plant growth Deeper plant roots Increased ground cover Reduced erosion Improved soil biology Non selective grazing of plant species
Breeding & finishing livestock on a single farm or station	Between region animal production supply chains	Farmers backgrounding pastoral cattle for station owners, exporters and meat processor	Cattle are moved off green feed in the north at the end of the summer growing season and on to farms in the NAR at the start of the winter growing season. Higher animal turnoff per breeding cow Younger age for slaughter from higher year round growth rates Reduced stock rates in non growing season results in less erosion and vegetation degradation Lower costs of production and increased profit

Traditional grazing management	Feed supply/demand budgeting to match feed demand to supply	Holistic Management & Grazing For Profit training and grazing charts 'Pasture from space' MLA feed supply demand calculator	Prevents both over grazing and under grazing Livestock numbers adjusted early when drought starts Stock sold at higher prices Low hand feeding costs Prevents erosion from over grazing in drought Increase in percentage of feed harvested by stock
Rotations with annual pastures & winter grain crops	'Pasture cropping' where winter grain crops are grown over summer active / winter dormant, sub tropical perennials	Colin Seis in NSW DAFWA trials at Geraldton	Increased perennial grass density Increased summer feed Grain yields maintained Less weeds, pests insects and disease Lower costs of fertiliser and herbicides Increased ground cover & reduced erosion Increased soil carbon Improved soil biology
In crop weed control with chemicals	In crop grazing by sheep to control weeds and manage canopy density	Don Nairn at Binnu DAFWA trials	Early winter grazing of crops defers grazing on other pastures Higher stocking rates than annual pastures (e.g. 0.4 vs. 7 DSE/ha) Higher summer ground cover and reduced erosion Cheaper weed control Non chemical weed control to reduce herbicide resistant weeds Reduced leaf canopy results in higher grain yields in drought
Farming systems focused on mineral fertiliser	'Biological farming' system focus on improved soil biology	David Cook at Dandaragan	Lower input costs Maintained meat production Improved ground cover Possibly high humification rates of labile soil carbon
Traditional commodity marketing	'Environmental friendly' branded products	MIG EMS marketing of grain	Access to specialty markets Price premiums yet to be realised

Appendix 2; Model of measuring, verifying and trading soil and vegetation carbon sinks



Appendix 3

Drought proofing grazing systems – a case study from Binnu 2006/07

Tim Wiley & Rob Grima, Department of Agriculture & Food WA, Geraldton

ABSTRACT

A project commenced in early 2006 in the Binnu region investigating the possibility of increasing stocking rates whilst reducing erosion. The project involved 8 farmers who had a variety of innovative grazing systems established. Stocking rates for every paddock on the farms were calculated from the stock movement records, and adjusted for hand feeding. Ground cover was measured for the paddocks on the 23 May 2007 before the break of season. The results from two farms are presented.

On one of the farms established perennial grass (6.37 DSE/ha) and tagasaste (6.19 DSE/ha) carried more stock than annual pasture on sand (0.83 DSE/ha) and gravel (3.04 DSE/ha). It was found that for each extra Dry Sheep Equivalent per hectare there was 10% less ground cover in autumn with annual pastures. For any given stocking rate the perennial grasses had 41% more ground cover in autumn than annual pasture on gravel, and 79% more than annual pasture on sand. The farm carried 2,142 DSE for the 12 months and 41% of the land was badly eroded. It is predicted that if all the sand was established to perennials then the farm could have carried 4,268 DSE through the drought without causing erosion.

AIM

The Binnu region of the Northampton Shire experienced their worst season on record during the 2006 winter and into 2007 autumn. Rainfall from May 2006 to April 2007 was only about 30% of the long term average.

Farmers in this region had to reduce stock numbers by 50 to 100%, with almost all remaining stock having to be hand fed during autumn 2007. Crop yields were also reduced by more than 80% and no grain was delivered to the bin from this region. Erosion was wide spread and severe. Winds of approximately 100 km/hr on the 9 March 2007 blew away much of the remaining stubbles and dry pasture. Hundreds of kilometres of fencing were covered with sand.

The aim of this project is to compare the affect of annual and perennial pastures on carrying capacity and autumn ground cover in an extreme drought.

METHOD

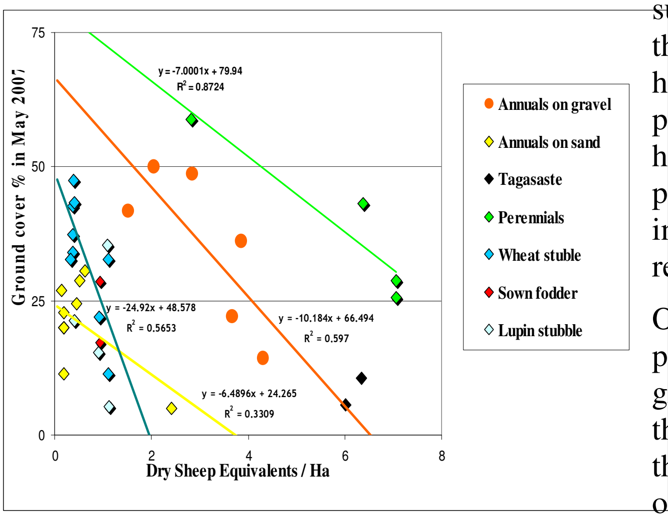
A range of new pasture systems are being trialled by farmer members of the Northern Agri Group (NAG) in the Binnu region of WA. An NLP / NACC funded project has monitored all paddocks on 8 selected farms. The stocking rate for the growing season (May 2006 to April 2007) was calculated from the farmers stock movements records. Grazing records were adjusted to Dry Sheep Equivalents (DSE). The DSE numbers were reduced to account for hand feeding at 1 kg feed = 1 DSE grazing day. Ground cover was assessed visually at 15 sites in each paddock in late autumn (23 May 2007). Satellite imagery was also used to assess ground cover, but it was not accurate in all paddocks.

The results from Jim Wedge's farm at west Binnu are presented here (with additional data from Murray Carson's presented in the graph). The Wedge farm has two soil types (sand and gravel). Annual paddocks were either volunteer pasture or oats sown for grazing. Tagasaste and sub tropical perennial grass mixes had been sown on some sand paddocks. Two of the three perennial grass paddocks were only sown in August 2006 and are not yet mature.

RESULTS

Established perennial grasses and tagasaste carried significantly more stock than annual pastures and grazed oats. Despite this heavy grazing, the perennials had adequate ground cover to prevent erosion. Annual pastures and cereal fodder crops suffered major wind erosion throughout the 2006/07 summer. With annual pastures and fodder oats, increasing the stocking rate resulted in less ground cover in autumn. For each 1.0 DSE/ha extra there was 10% less ground cover in late autumn. This reduction in ground cover was similar for both the sand (-10.7 % per DSE, R^2 = 0.8704) and the gravel paddocks (-10.2 % per DSE, R^2 = 0.597) on the Wedge farm. With the annual pasture and fodder oats, at any given stocking rate there was 34% more ground cover on the gravel paddocks than the sand paddocks.

The sand in the inter row of tagasaste had only 9% ground cover. However, these paddocks did not erode as the tagasaste effectively gives a 1 ½ m tall wind break very 8 m across the paddock.



The whole farm carried 2,142 DSE for the 2006/07 season at 2.37 DSE/ha, but suffered severe wind erosion over 41% of the whole farm. The safest strategy would have been to run no stock on the sand paddocks and only 1,918 DSE on the 529 ha of gravel, tagasaste and established perennial grass. This would have resulted in an 11% reduction in stock, but a 75% reduction in the area grazed.

Our results suggest that if all the sand paddocks were established to perennial grass + rotational grazing and tagasaste, then the farm could have run 4,268 DSE through the 2006/07 drought at an average of 4.72 DSE/ha with no erosion.

DISCUSSION

If we assume the established perennial grass paddocks has the same relations ship between stocking rate for the year and late autumn ground cover as for annual pastures (i.e. -10% ground cover per 1.0 DSE/ha), then at equivalent stocking rates the perennial grass + rotational grazing on sand would have 41% more ground cover in autumn than the annuals on gravel, and 79% more than the annuals on sand.

For the 2006 drought on the Wedge farm it would have been possible to run 2 DSE/ha on annual pasture and fodder oats in the gravel paddocks and not cause erosion (i.e. 50% ground cover target). There would have been 66% ground cover if there had been no grazing in these gravel paddocks. With the annuals on sand paddock there would have only been 32% ground cover in sand paddocks if not stocked. So erosion was inevitable even without grazing the sands. The perennial grass in the sand paddock could have carried 5.5 DSE/ha without the risk of erosion.

CONCLUSION

It is considered that there should be a minimum of 50% ground cover in autumn to prevent erosion. Most of the Binnu region suffered from wind erosion and the' 50% ground cover' rule seemed to be appropriate. This project has shown that a shift to a perennial pasture based grazing systems could cope with extreme droughts. The perennial pastures themselves could make a significant contribution to limiting climate change through the sequestration of Carbon in the soils. Soil tests before and after establishing Jim Wedges first perennial pasture paddock suggests that the perennial grasses could be sequestering 15 t CO_2eq /ha/year. However, much more detailed soil testing would be required to accurately determine the sequestration rate.

The project will continue until the end of the 2008 season. Hopefully 2007 is a wetter years so that impact of perennials can be assessed in a more normal season. The results will be used to conduct whole farm economic analysis of these high stocking rate systems. Soil samples have been collected to determine how much Carbon is being sequestered under the perennial pasture systems. The potential for Carbon Credits will be included in the economic analysis.

The 2006 drought was an extreme weather event. Events like this could be expected every few centuries as part of natural climate variability. Alternatively, this drought fits with the 'global warming' scenarios. If droughts like this did become more common, traditional agriculture will collapse in the northern sand plain region. Farmers could not sustain many events that caused as much environmental and financial damage as the 2006 drought.

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Paper reviewed by: Wayne Parker, Department of Agriculture & Food WA, Geraldton