THE POTENTIAL OF GREENHOUSE SINKS TO UNDERWRITE IMPROVED LAND MANAGEMENT: A CASE STUDY FROM WESTERN AUSTRALIA

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Abstract
The current agricultural systems of broad areas of Australia are unsustainable, with large projected increases in salinisation, decreases in water quality and losses of biodiversity. Increased concentrations of greenhouse gases have been linked to global warming. The international response to this warming, the United Nations Framework Convention on Climate Change and its Kyoto Protocol, include provisions that enable greenhouse sinks, or the sequestration of carbon in soils and vegetation to be used by Parties as one strategy to fulfil their obligations. The Kyoto Protocol, which is yet to be ratified by Australia, also allows for trading in emission reductions, and this opens the possibility that investment in carbon sinks may help underwrite broader natural resource management objectives. This paper describes a study that examined the possibilities for improved land management in Western Australia arising from the development of carbon sinks. This considered (a) the likelihood of a carbon market developing and the likely depth of that market as a result of current national and international policies, (b) the data available to provide estimates on different types of sinks and (c) the likely benefits of wide-scale sink investment. The study was designed to quantify an upper limit to sink potential.

It was estimated that the total amount of carbon that could be sequestered by revegetating 16.8 Mha of cleared farmland was 2.2 Gt CO_2-e, and 3.3 Gt CO_2-e by destocking 94.8 Mha of Western Australian rangelands. It was considered that there were insufficient data to produce estimates of sequestration following changes in tillage practice in cropping systems or the revegetation of already salinized land. We conclude that carbon sinks are only likely to become profitable as a broad-scale stand-alone enterprise when carbon prices reach A$15/t CO_2-e. However, below this price their value can be significant as an adjunct to reforestation schemes that are aimed at providing other products (wood, pulp, bioenergy) and land and water conservation benefits. Irrespective of this, carbon sinks provide an opportunity to both sequester carbon in a least-cost fashion and improve soil and watershed management.

Introduction
A number of major environmental issues currently confront Australia. These include the relentless salinization of land and water resources, recurrent wind and water erosion of both cultivated agricultural land and rangelands and the prospect of continued climate change due to increases in the concentration of greenhouse gases in the atmosphere. In south-western Australia it is estimated that without remedial actions that up to 7 Mha of land will be affected by salinity by 2050 (National Land and Water Resources Audit, 2001), all inland water supplies will be salinized, up to 450 species are at risk of extinction and apart from significant loss of farmland productivity (Kingwell *et al.,* 2003) there is significant threat to infrastructure (State Salinity Council, 2000). Similarly, large areas of rangeland are degraded. Noble *et al*. (1996) summarize several rangeland condition surveys in Western Australia, with 50 to 94% of the land considered to be in a “deteriorating” or “degraded” condition.

Although it has been recognized that the scale of the salinity problem is huge, and that strategically located reforestation of farmland will help tackle the problem, any investment in reforestation from public funds is likely to be limited. If commercial drivers can be identified, investors will establish trees for profit, with collateral environmental benefits. A striking example in Western Australia has been the use of outside investment to fund farmland reforestation, a plan advocated in the late 1980’s (Bartle and Shea, 1989; Shea and Bartle, 1988). Almost 250000 ha of *Eucalyptus globulus* plantations have been established by private investors and where trees have been established in partially cleared water catchments, such as that of the Denmark River, there is evidence that the trends of increasing stream salinity have been reversed (Bari *et al.,* 2004). In the rangelands, changes in stocking practice may reverse land degradation processes.

The establishment of trees in higher rainfall areas is profitable, due to both relatively high growth rates and proximity to infrastructure. In lower rainfall areas (less than 600 mm year^{-1}) trees grown for wood production alone are often not profitable and other sources of income from the trees are required to make the venture profitable. The concept of 'self funding Landcare' has thus been further explored with investigations of other products available from trees such as carbon sequestration (Biggs and Bartle, 1999; Shea *et al.*, 1998), Bioenergy and eucalypt oils (Bartle 2001) and improved water quality (Harper *et al*., 2001).

Increased atmospheric concentrations of greenhouse gases, in particular carbon dioxide, have been linked to global warming and global climate change. The international response to this warming, the United Nations Framework Convention on Climate Change and its Kyoto Protocol, include provisions that enable greenhouse sinks, or the sequestration of carbon in soils and vegetation, to be used by Parties as one strategy to fulfil their obligations. The Kyoto Protocol also allows for trading in emission reductions, and this opens the possibility that investment in greenhouse sinks may help underwrite broader natural resource management objectives (Shea, 1998; Shea *et al.*, 1998). This linking of greenhouse sinks with other benefits is implicit in several prototype programs being developed across Australia. Western Australian examples include the establishment of *Pinus pinaster* on farmland for BP by the Forest Products Commission, and the establishment of oil mallees for the Kansai Power Company by the Oil Mallee Company.

This paper describes opportunities for the land management sector in Western Australia arising from greenhouse gas abatement and in particular the development of carbon sinks as a result of land-use change. It summarizes a recent scoping study (Harper *et al.*, 2003) that considered (a) the effect of current national and international policies on carbon market developing and the likely depth of that market, (b) the data available to provide estimates on sequestration in different types of sinks and (c) the likely benefits of wide-scale sink investment.

The Kyoto Protocol and Prospects for Emission Trading

The increasing recognition that global climate is being changed due to the accumulation of greenhouse gases has resulted in a range of national and international activity. The United Nations Framework Convention of Climate Change (UNFCCC) was opened for signature 1992, and entered into force in 1994, with Australia as a ratifying Party. This treaty recognises human-induced climate change as a problem, and established a framework with an ultimate objective of stabilising greenhouse gas concentrations. A series of conferences of parties to the convention (COP) meetings ensued, with the COP 3 meeting at Kyoto in 1997 resulting in the negotiation of the Kyoto Protocol (United Nations Framework Convention on Climate Change, 1997). The Kyoto Protocol consists of a series of actions by 39 industrialised countries (Annex B) to reduce global carbon dioxide emissions by 5.2% in the period 2008-12 ("the first commitment period") relative to 1990 ("the baseline"). There are no restrictions on non-Annex B countries. Australia was able to argue for an increase in net emissions, to 108% of the 1990 base-line in 2008-2012, some other industrialised countries within the European Union will be able to increase emissions although the EU in toto will be required to reduce its emissions.

While carbon dioxide is the best-known greenhouse gas Kyoto Article 3.1 identifies six greenhouse gases (carbon dioxide, methane, nitrous oxide, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride). Amongst other sources, methane is produced from ruminant livestock and landfills. Nitrous oxide is emitted from agricultural soils with emission rates linked to the application nitrogen fertilizer as well as environmental conditions including soil-type, temperature and the water regime.

The Kyoto Protocol opens the possibility of sequestering carbon in sinks (Sampson and Scholes, 2000; Schlamadinger and Karjalainen, 2000), and subsequent trading through a number of articles.

Article 3.3: Carbon sinks

The counting of sinks within the land use, land use change and forestry (LULUCF) sector, from afforestation or reforestation of previously cleared land. Only carbon sequestered in plantations established after 1990, that is on land that was cleared on the 1st January 1990 and was not part of a forest products cycle, can be counted.

Article 3.4: Additional sink activities

Each Party may choose to apply all or a selection of additional activities – forest management, cropland management, grazing land management and revegetation during the first commitment period (2008-2012). Emission reductions claimed must be proven to be human-induced and to have occurred since 1990. These are termed "additional activities" and include the sequestration of carbon in agricultural soils, rangelands (biomass and soils), pre-1990 plantations and re-planted vegetation not considered to be "forest". Australia has elected not to consider forest management, and it is not considered further here.

Articles 6, 12 and 17: Joint implementation (JI), clean development mechanism (CDM) & international emissions trading
These articles establish a market-based approach to emissions reduction by allowing developed country parties to trade parts of their assigned emissions and certified emissions reductions, and also to generate emission credits through abatement projects in developed (JI) and developing (CDM) countries that are parties to the Protocol.

Thus, if the Kyoto Protocol comes into force, it will formalise the global emissions market based around the three Kyoto mechanisms – international emissions trading, CDM and JI. The prospects for Australia to be able to participate in such a global emissions market depend on a number of factors including:

- The development of international emissions trading under the Kyoto Protocol,
- Australia's attitude towards ratification of the Protocol and alternative policies, and
- Assessment of emissions trading as a favoured domestic policy option.

The study was undertaken under the assumption that the Kyoto Treaty, or a derivative treaty, would eventually be ratified, and that an international emissions trading market will thus exist. As a pre-cursor to such a global market, emissions trading across the 25 member-states of the European Union is already scheduled to begin in 2005 and linkages are being sought with other countries. Nonetheless it should be borne in mind that Australia may not be able to participate in this growing global market by virtue of not ratifying the Kyoto Protocol. Carbon markets may exist outside the Kyoto Protocol, however these will be dependent on state government and/or private initiatives.

In the absence of a formal market there may be opportunities for bilateral deals with organizations seeking to reduce their greenhouse emissions, or those seeking to learn about the feasibility of carbon trading. However, the possibility that, under current federal government policy settings, there may only be a limited market for carbon sequestered in Western Australia (and Australia more generally), compared to what would prevail with ratification of Kyoto, must be recognised.

Carbon Farming Issues

A range of issues, related to the establishment of carbon sinks on farmland are pertinent. There is a particular need to adequately predict, measure, certify and verify any carbon sinks. Particular challenges will occur with plantings of trees and shrubs based on diverse species (biodiversity or Landcare plantings). Carbon pooling may be an option for small-scale projects where a balance is being sought between accounting and cost.

All sequestration projects are subject to some degree of risk associated with factors such as drought, fire or pests. These risks can be reduced by rigorous site and species selection and sink management (Harper and McGrath, 2000).The market may account for risk by reducing the price paid for carbon. "Risk discounting" allows a buffer for unforeseen circumstances and/or inaccurate estimation and reduces the chances that the seller will be unable to supply the contracted quantity. Reducing uncertainty will reduce the risk discount and thus improve the profitability of carbon schemes. The process of establishing the appropriate risk discount for a project involves taking into account a wide range of characteristics of the project. Such characteristics and factors that could affect the level of risk discounting are outlined in Table 1. It is conceivable that under high-risk conditions the risk discount could be large, and this will have a significant impact on the commercial returns to the project.

Table 1. Factors affecting the risk discount of carbon sinks

	Risk Discount	
Characteristic	**Low**	**High**
Type of project	Commercial, monoculture	Non-commercial, diverse spp.
Area	Well defined blocks	Irregular & dispersed
Management	Active management regime	Not closely managed
Growth models & carbon accounting	Well researched & documented	Speculative & uncertain
Kyoto compliance	Certain	Uncertain
Monitoring & reporting	Regular & comprehensive	Irregular & partial

To market carbon credits a title is required and the Western Australian Carbon Rights legislation will meet this requirement. An important issue, when establishing a carbon sink is that of permanence. In simple terms this means that if carbon credits are sold following the establishment of a sink, they will have to be re-bought if the land-use is later changed to a state that holds less carbon.

Carbon Sequestration Potential

Existing Western Australian data related to prospective Kyoto Article 3.3 and Article 3.4 greenhouse sinks were examined and estimates made of the likely amounts of sequestration using various models.

Article 3.3 Sinks: reforestation of agricultural land

For the agricultural region an estimate was made of the area of cleared farmland, by identifying and excluding urban areas, and any existing natural bushland. A carbon sequestration surface for the agricultural region of Western Australia was developed using the VAST model (Barrett, 2002; Xu and Barrett, in review) based on climatic and soils data. This surface shows the predicted equilibrium carbon sink following reforestation of farmland with native vegetation. The equilibrium (long-term average) carbon sink from reforestation with commercial timber species will differ from native vegetation. Generally carbon sequestration rates will be higher as the commercial species are selected and bred for high stemwood production rates (Ritson and Sochacki, 2003), but may be less under frequent harvest (short-rotation) management. Under current international rules, when timber is harvested it is assumed that the sequestered carbon is immediately released to the atmosphere. However, in reality, carbon is retained in wood products. If accounting for carbon in harvested wood products is recognised in the future it will make timber plantations a lot more attractive in terms of carbon sequestration.

Sequestration data were aggregated on the basis of local government areas, with the maximum potential sink estimated to be 2,091 Mt CO_2-e, across 16.7 Mha of cleared farmland. For specific local government areas the amount of sequestration varied from 20 to 496 t CO_2-e/ha, and this varies in a general fashion with rainfall. These estimates may be conservative for drier sites, while trees grown in strips, with access to water from adjacent farmland will have higher rates of carbon sequestration.

This estimate is of the total potential sink, such that if all land were reforested – this is unlikely to be the case, but it provides a useful benchmark nonetheless, when considering carbon sinks. The amount of actual sequestration will depend on the amount of change from present land uses, and no assumptions are made about the rate of this change, as it will depend on factors such as the price of carbon relative to other farm commodities, and landholder preference. The amount of sequestration will also vary with soil conditions and will be considerably lower on land affected by salinity, or with shallow or sandy soils, compared to land that has deep, fertile soils.

Article 3.4 sinks: additional activities

Grazing land management

In the rangelands there are 94.8 Mha of land currently used for grazing. Much of this is leased from the Crown, so there is an issue about the ownership of any carbon that may be sequestered. In this case the VAST model was combined with RangeASSESS, a scenario calculator, to estimate the amount of carbon that would be sequestered after a 20 year period, following 100% destocking (Hill *et al.*, 2003; Hill *et al.*, 2001). The estimate was the mean of individual calculations for every possible 20 year climate period in the historical record using starting years from 1889 to 1999, with this working best for 5 year reporting periods (Hill *et al.*, in prep.). Over the 20 year reporting period used here, effects of both favourable and unfavourable climatic cycles are smoothed out by the simple averaging used in the calculations. Here the total sink that would result from 100% destocking, after a 20 year period, was estimated to be 3072 Mt CO_2-e in biomass and soils. Since RangeASSESS was designed primarily to look at effects on soil carbon stocks, and there are major approximations in the biomass change models in RangeASSESS, the biomass estimate may be substantially less reliable than the soil estimate from this analysis. For specific local government areas the amount of sequestration varied from 4 to 133 t CO_2-e/ha.

These estimates represent the potential storage, and it should be stressed that the scenario calculator is not a process model or accounting tool. It is designed to provide approximate magnitudes and a direction of potential changes in carbon stocks and was not specifically calibrated for Western Australian conditions for this study. Similarly, the stability of any carbon sinks with fire is uncertain and it is not clear whether it is possible to quantify small increments of carbon change in rangeland systems cost-effectively. There may therefore be considerable transaction costs associated with this carbon, compared to other sinks. A clear policy definition regarding the eligibility of grazing land sinks is also required.

Revegetation
It was estimated that 2.1 Mha of land was already affected by salinity and The National Land and Water Audit suggests that up to 30% of farmland may be salinized by 2050 (National Land and Water Resources Audit 2001). Large amounts of land could thus be potentially available for the development of sinks through the establishment of trees and saltbush (*Atriplex* spp). Although no data are available in the public domain to support the proposition (Grierson et al. 2000), the establishment of saltbush will represent a carbon sink –in terms of the above and below ground biomass. Even less verified work on changes in soil carbon has been undertaken. However, given the particular accounting rules operating under the Kyoto arrangements it does not automatically follow that a carbon credit would be generated. It is also certain that the amounts of carbon will be less than that stored in forests in similar rainfall areas as (a) the systems will be grazed and (b) plant productivity from salinized sites will be less than that from non-saline areas. Annual forage production from saltbush/bluebush shrublands in WA has been estimated as 0.8 to 1.0 t ha^{-1} yr^{-1} (Barson *et al.*, 1994).

Cropland management
There is considerable interest in using changes in cropland management to store carbon in soils in north America (Lal *et al.*, 1998). The basic concept is that increases in carbon storage will follow conversion from conventional to no-till cropping, with this also resulting in a decrease in soil erosion. Income from carbon credits may thus underwrite a more sustainable agricultural system. There are insufficient data to make more than rough estimates of the amount of carbon that could be sequestered via cropland management, in Western Australia, and this is a priority area for further research.

As with revegetation, issues that need resolution include the potential size of the sinks, the cost effectiveness of their establishment, likely difficulties in prediction and measurement and ascertaining whether such sinks will be accepted as valid forms of emission reduction under national and international rules. In the case of saltbush, the response of the systems to grazing will also need to be considered with any analysis of carbon sequestration potential undertaken on a farming-systems basis and taking into account reduced emissions of methane and nitrous oxides from waterlogged and salinized soils and increased emissions of methane from grazing livestock.

Profitability of Carbon Sinks
The overall profitability of establishing carbon sinks on farmland was examined at different prices of carbon, with the analysis being undertaken for nominal prices between A$5 and A$15/t CO_2-e. Two approaches were taken, (a) the development of case studies for different forestry enterprises at 300, 600 and 900 mm annual rainfall, with income from timber at various periods over a 60 year period, and (b) an analysis of the profitability of an enterprise established purely for carbon, with and without land rental. Under the applied assumptions there are only two situations where carbon farming returns a positive NPV in its own right. These are for *E. saligna* in the 900 mm rainfall zone and *P. pinaster* in the 600 mm rainfall zone at $15/t CO_2-e. Comparing the returns from these prospective carbon-only activities with the prevailing agricultural activity benchmarks ($1150-$1350 for 900 mm zone and $950-$1150 for 600 mm zone), however, would suggest that they are unlikely to be commercially attractive if they had to compete directly with current activities.

While growing trees purely for their carbon sequestering potential is not likely to be commercially viable, at least under current and expected market conditions, the value of carbon could still make a valuable additional contribution to forestry activities pursued for other reasons, such as commercial timber production and salinity amelioration. The analysis here indicates that, for commercial forestry activities, and assuming carbon credit prices of $5/ t CO_2-e, the value of the carbon could add 0.8 – 1.7 percentage points to the enterprise return. This would increase to 2 - 4 percentage points for carbon credit prices of $10/ t CO_2-e and 3 – 6 percentage points for carbon prices of $15/ t CO_2-e.

Socio-economic benefits
The socio-economic impacts of carbon sinks were also considered, with a multiple range of benefits considered likely including improved land and water conservation benefits, wildlife habitat and recreation values. Salinity is a major environmental issue in WA and greenhouse sinks may provide a means of underwriting the necessary investment in revegetation. Only where extensive forestry development displaces existing farming communities are there likely to be disbenefits; this will not occur where carbon sinks are promoted as an integral part of farming systems.

Conclusions

It is clear that there is a large potential carbon sink in Western Australia through both the reforestation of farmland and the destocking of pastoral lands. Although carbon sinks are generally unlikely to be a profitable enterprise as a stand-alone enterprise under present price projections, their value will be as a valuable adjunct to reforestation schemes that are aimed at providing other products (wood, pulp, bioenergy) and land and water conservation benefits. Many current agricultural systems are unsustainable, with large projected increases in salinization and losses of biodiversity, and partial reforestation via carbon investment will help stabilize these.

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