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Greenhouse, Land Management and Carbon Sequestration in Western Australia

A report prepared by the Department of Agriculture Western Australia, Department of Conservation and Land Management, Forest Products Commission and Department of Environment, Water and Catchment Protection on behalf of the Western Australian Greenhouse Task Force

This report was coordinated by the Department of Agriculture

December 2002

Department of Agriculture
South Perth, Western Australia

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EXECUTIVE SUMMARY

This report examines options for greenhouse emissions abatement by changing land management practices and establishing terrestrial organic carbon sinks in Western Australia. It recommends the following priorities to the Greenhouse Task Force.

- Expand the already successful and flourishing Kyoto Protocol Article 3.3 plantations, as carbon sinks.
- Determine the potential of Kyoto Protocol Article 3.4 sink activities (cropland management, grazing land management and revegetation) to contribute to carbon sequestration in Western Australia.
- Promote appropriate Kyoto Article 3.4 sink activities.
- Assess how the 'Carbon Bank' initiative being investigated by the Greenhouse Taskforce could provide the Land Management sector with a major source of investment in greenhouse offsets and improved natural resource condition.
- Encourage the development of bioenergy industries.
- Review the current methodology for savanna burning and prepare a submission to the NGGI Steering Committee and the Australian Greenhouse Office requesting that the methodology for estimating emissions reflect the distinct differences in fuel load between the north and south of the State.
- Promote methods to reduce methane emissions from ruminants, including improved grazing management and ruminant anti-methanogen technology, when it becomes available.
- Continue involvement in current research determining baseline figures for emission levels from agricultural practices.
- Improve knowledge of climate change impacts on Western Australia through climate science and agricultural systems modelling.

Together these actions provide two integrated initiatives to greenhouse emissions abatement for the Land Management sector.

1. Using integrated, whole-farm enterprise responses to develop Good Agricultural Practice Protocols.
2. Development of policies that encourage the establishment of terrestrial carbon sinks in a manner that achieves natural resource management outcomes.

The Western Australian agricultural and forestry sectors (for the purposes of this report, termed the Land Management sector), produce a large proportion of Western Australia's total greenhouse gas emissions and have the capacity to sequester a large amount of atmospheric carbon. It is in the long-term interests of the Land Management sector that it investigates and implements effective practices to reduce its greenhouse gas emissions and enhance the amount of carbon it sequesters.

Carbon sinks offer great potential for the Land Management sector to contribute to greenhouse emissions abatement. Based on current expectations for the expansion of Kyoto Protocol Article 3.3 Sinks in the State, sinks will sequester 10 per cent of the State's emissions in the first Kyoto commitment period based on actual 1999 State emissions, rather than the projected emissions for this period. Some of the sequestered carbon could be traded through international Greenhouse emissions trading systems, if Australia and the particular carbon sequestration activity met the requirements of the international market. This international market currently recognises two types of carbon: carbon sequestered in tree plantations established on land that was not forested or vegetated in 1990 (Kyoto Article 3.3); and carbon sequestered in vegetation or soils as a result of changed land management practices (Kyoto Article 3.4).

The State Government's *Action Plan for Tree Farming in Western Australia* (Forest Products Commission) outlines significant targets for Kyoto Article 3.3 compliant tree farming throughout the agricultural areas. There is also considerable capacity for atmospheric carbon to be sequestered through the growth of other vegetation in agricultural or pastoral areas.

Kyoto Protocol Article 3.4 sinks include storing carbon in soils under cropland and grazing land management, and various forms of revegetation that do not qualify as plantations under Article 3.3. The potential of these sinks is uncertain, but could involve vast areas of land in Western Australia. Even if management changes achieve modest annual sequestration rates, such activities might store very large quantities of carbon because of the huge areas potentially affected.

The Department of Conservation and Land Management and the Forest Products Commission developed practical and effective means of estimating carbon sequestration methodologies for some common Western Australian tree plantations, as part of the Cooperative Research Centre (CRC) for Greenhouse Gas Accounting and other research programs. Further research needs to be undertaken to clarify the long-term carbon storage potential of Article 3.4 sinks.

The State's *Carbon Rights* legislation will enhance certainty of ownership for sequestered carbon. However the State needs to monitor proposed international and national policies that might affect the capacity of carbon sequestered in Western Australia to be traded for value in carbon emission markets.

The Land Management sector also offers the State a potential bioenergy industry, with bioenergy acting as an alternative to fossil fuel used in transport and power generation.

It will be a major challenge for agriculture to achieve significant reductions in emissions by changing management practices and, largely due to limitations in inventory methodologies, to demonstrate its achievements. Many of the equations and constants used in the National Greenhouse Gas Inventory methodology are based on limited research undertaken in the eastern States of Australia. Due to the different soil types and climate experienced in Western Australia, there is concern emissions estimates for Western Australia are likely to be inaccurate and possibly over-estimated. They provide an unsatisfactory basis at a State and Regional level for indicating how changes in agricultural management practices will reduce emissions and could misinform policy development aimed at reducing emissions.

Moreover, the potential to reduce emissions from agricultural operations should not be overstated. Australian agriculture has already made significant changes to management practices and farming systems over recent decades. These have seen agricultural productivity increase by almost one-third since 1990 with a minor increase in aggregate emissions. Western Australia is leading the nation in the adoption of minimum tillage and stubble retention practices, which has been greenhouse positive. Regulation of land clearing since1987 has reduced emissions from this source to very low levels compared with eastern Australia. Amendments to the Environmental Protection Act are before the WA Parliament, and are likely to be passed when Parliament resumes early in 2003. These amendments include improvements to clearing regulations, increased penalties for illegal clearing of native vegetation and the introduction of a principle against 'environmental harm'.

The legislation includes provision for penalties for damage to vegetation through fire or grazing where applicable. It is expected these amendments will further reduce emissions.

It is not clear that major transformations in many agricultural management practices would yield commensurate reductions in emissions. A considerably enhanced research effort is required to confirm the best opportunities but current knowledge indicates the greatest opportunity for reducing emissions from agricultural practices is methane from ruminants.

As research progresses on emissions from the Western Australian Land Management sector, practices for minimising emissions will become apparent and guide producers in adopting appropriate management changes. To this end the Department of Agriculture is a supporting partner in the successful bid by the Cooperative Research Centre for Greenhouse Accounting to expand its research program into emissions from agriculture of methane and nitrous oxide.

Changes in practices to reduce emissions will only be reflected in the State's total greenhouse emissions if they are a part of the National Greenhouse Gas Inventory. The inventory effectively models emissions from south-west sheep and cattle and intensive animal industries. Other emissions, including rangelands sheep and cattle, are not so well captured with burning, fertiliser use and background soil emissions being the only other parameters incorporated.

Tables on potential carbon sequestration and emissions reduction in the Land Management sector are included in the Appendices. The tables should be considered a 'work in progress', reflecting the lack of research to date for many of the activities in Western Australia and current inadequacies in greenhouse accounting methodology. They do, however, assist in the identification of priorities for further investigation.

This report paper is split into three sections. The first section gives information on the main greenhouse gases in the Land Management sector and the biological pathways that lead to their production; the second section discusses what greenhouse means for the Land Management sector; and the third suggests focus areas for the Land Management sector with regard to greenhouse.

1. SETTING THE SCENE

Some atmospheric gases, such as water vapour, carbon dioxide, methane and nitrous oxide, capture energy emitted from the earth's surface and so prevent a portion of the heat energy reflected from the earth returning to space. Such 'greenhouse gases' wrap the earth in a thermal blanket keeping it warm enough to sustain life. Without this 'Natural Greenhouse Effect' the average temperature on the earth's surface would be a chilly –18 degrees rather than the life sustaining 15 degrees we enjoy.

The 'Enhanced Greenhouse Effect' resulting from human activities during the past 250 years has increasingly become a serious international concern with greater certainty that rapidly rising concentrations of greenhouse gases in the atmosphere will cause the lower atmosphere to warm at a rate and to levels unknown in human history and scientific knowledge. These changes are projected to alter global climate patterns and regional climate conditions.

The world's community has sought to address this issue through the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol to the UNFCCC. These agreements set out a framework for international action to reduce the rise in greenhouse gas emissions and to reduce the impact of climate change on human interests and the natural environment. As international agreements, they provide a broad set of rules within which nations are expected to conduct their activities. It is important that the development of further international rules and their application in Australia recognises the particular circumstances of Western Australia.

To keep an inventory of greenhouse emissions, industry has been split into six sections.

1. Stationary energy
2. Industrial processes
3. Transport
4. Agriculture
5. Land use change and forestry
6. Waste

The land management sections are agriculture and land use change and forestry. For the purpose of this report they will be referred to as the Land Management sector.

1.1 Greenhouse gases and their relevance to land management

Agriculture (18%) and land use change and forestry (7%) combine to contribute 25 per cent of Australia's greenhouse gas emissions, but the majority are not produced through the consumption of fossil fuels as is the case with most industries.

Rather, carbon dioxide released from land clearing provides 12 per cent of Australia's total emissions, with 95 per cent of this figure apportioned to Queensland and New South Wales. Carbon dioxide sequestered from forestry and other sinks reduce emissions by 4.5 per cent of Australia's total emissions. Sixty-five per cent of emissions from the agriculture sector are livestock methane from enteric fermentation. It is estimated that 1 in 7 tonnes of Australia's greenhouse gas emissions (14 per cent) is from extensive livestock grazing.

Nitrous oxide is the other greenhouse gases emitted from the Land Management sector. The warming potentials of methane and nitrous oxide are 23 and 296 times the global warming potential of carbon dioxide, respectively. For convenience, all greenhouse gases are measured in carbon dioxide equivalents which has the symbol CO_2 –e. So to convert non-CO_2 gases to a common CO_2 –e value the amount of methane measured is multiplied by 23 and nitrous oxide is multiplied by 296.

Land management activities contribute to greenhouse gas emissions directly and indirectly. Direct contributions are from sources such as deforestation, biomass burning, ruminant animals, decomposition of soil organic carbon from tillage practices, rice cultivation, fertiliser application, use of manure, and degradation of wetlands.

Indirect effects, which account for most of agricultural greenhouse gas emissions, are attributed to emissions of nitrous oxides and methane from concentrated livestock operations and from microbial activities in soil and water following applications of fertilisers and manures.

So unlike other sectors, the bulk of greenhouse gas emissions from Land Management sector are not carbon dioxide but methane and nitrous oxide.

1.2 Carbon dioxide

International greenhouse gas accounting inventory methodology assumes there is a balance between uptake and emissions of carbon dioxide in agricultural crops and pastures and consequently does not account for carbon dioxide produced from standard agricultural practices. The assumption is that whatever carbon dioxide is released from agriculture will be taken up in new crops, pasture regrowth and other vegetation.

Some carbon dioxide emissions produced from agriculture are not accounted for under agriculture in the National Greenhouse Gas Inventory. Examples are carbon dioxide from the combustion of fuel (accounted to stationary energy), and carbon dioxide released from applied lime.

However, carbon dioxide accounts for the bulk of emissions and sequestration for the land use change and forestry sector. Carbon stored in vegetation is released when land is cleared and is stored in vegetation through forestry. The inventory methodology also assumes carbon is lost from soils over a number of years when native vegetation is cleared for agriculture.

The way in which carbon flows between the different stores is illustrated in Figures 1 and 2.

Figure 1 gives an overview of the carbon cycle at a global scale. It shows a small amount of carbon is stored in plants and soils, with the main stores of carbon being the oceans. This demonstrates that although carbon can be stored in plants and soils, the potential is not as high as fossil fuel storage or storage of carbon dioxide in the oceans. The increased levels of carbon dioxide in the atmosphere indicate a shift in the global carbon cycle. This is predominantly due to the release of carbon dioxide from the use of fossil fuels and land use change.

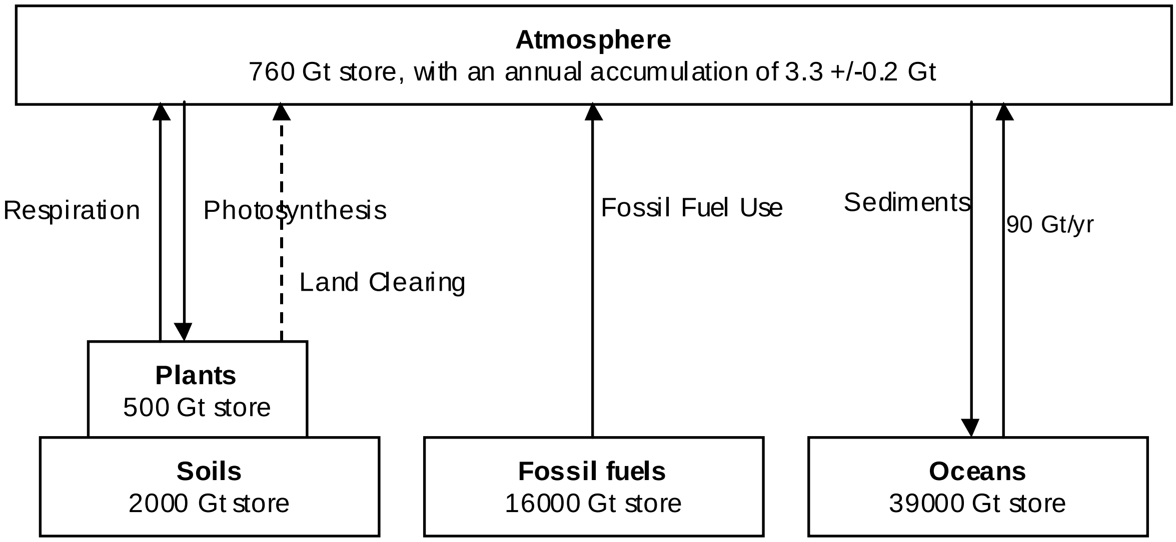

Figure1. The global carbon cycle (Gt = giga tonnes or 1000 million tonnes). (Source: CRC for Greenhouse Gas Accounting.)

Flow s occurring external to the w ater and earth boxes are fast, rapidly changing process, while those w ithin the boxes occur over greater periods of time. The box w ith dashed lines captures those flows in w hich agriculture has a role. The amount of carbon stored or emitted (arrows) through each of the carbon stores (boxes) can be manipulated to result in a reduction of greenhouse gas in the atmosphere. For instance rather than using fossil fuels as an energy source, plant products can be used in their place (e.g. biodiesel). This shifts the flow of carbon from fossil fuels to combustion tow ard the flow from plants to combustion. Another example is that of carbon sequestration through planting trees. This requires the flow between the plants and death stores to be slow ed, and the stores of carbon in the plants box to increase.

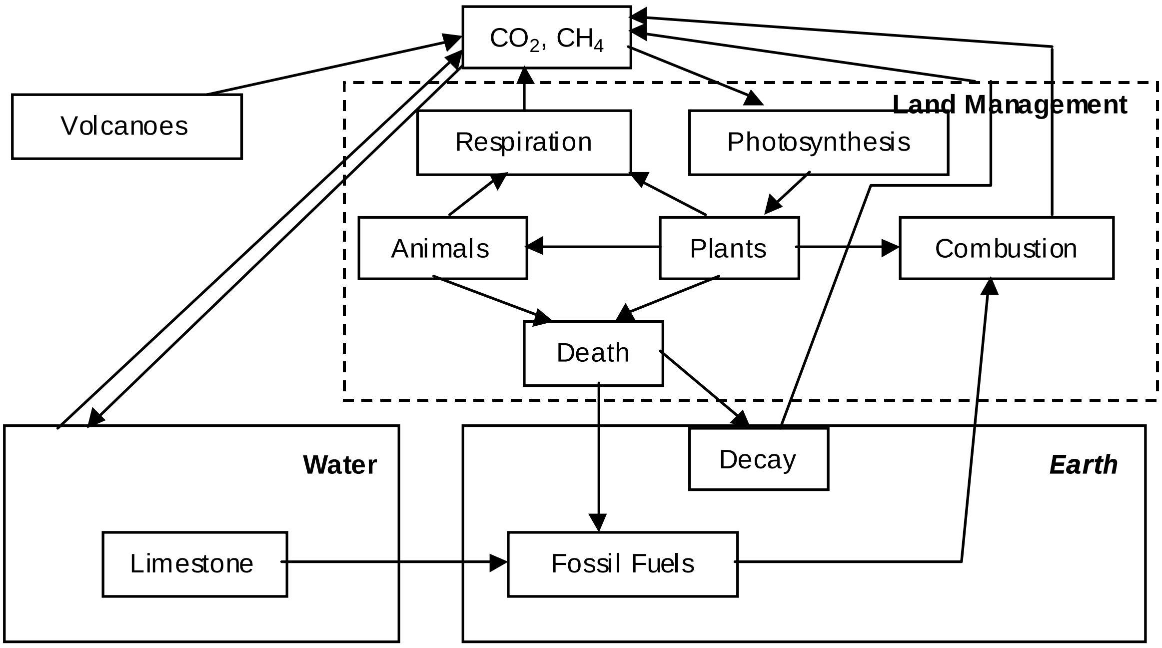

Figure 2. Flows of the global carbon cycle. The dotted line indicates those processes captured by the Land Management sector. (Source: CRC for Greenhouse Gas Accounting.)

1.3 Methane

The methodology for the estimation of methane production from animals is relatively well developed. However methane is also produced in other areas of the sector. Those accounted for in NGGI are produced in the combustion of fuel, clearing of land and the burning of agricultural residues and savannas.

There are other sources of methane emissions in the Land Management sector including methane from wetlands, swamps, termites and native species such as kangaroos. Generally, these are not considered anthropogenic sources and are not accounted for in the NGGI.

1.4 Nitrous oxide

Nitrous oxide is thought to account for about 20 per cent of the total greenhouse gas emissions (in carbon dioxide equivalents) from Australian agriculture and 2per cent from land use change and forestry. Therefore the Land Management sector contributes 22 per cent of total greenhouse gas from nitrous oxide.

Nitrous oxide emissions from the Land Management sector accounted for in the NGGI are from fertiliser, soils, animal excrement, burning of savannas, burning of agricultural residues and the combustion of fuels. Although the biophysical processes that produce nitrous oxide have been identified, the quantification of the emissions is deficient mainly due to the difficulty in measuring these emissions. With less than 10 reasonable data sets on the emissions of nitrous oxide from soils, the capacity to measure and develop abatement strategies is hampered.

The nitrogen cycle, illustrated in Figure 3, gives an overview of the flows of nitrogen in the agricultural system. Currently the actual magnitude of the flows is uncertain and research is being undertaken to further clarify the quantity of nitrous oxide emissions from agriculture.

However, the complexity of the summarised nitrogen cycle demonstrates that there are many areas for possible intervention. For instance, as soils get wet nitrogen begins to be lost in the form of NO (nitrogen monoxide). As it becomes wetter N_2O (nitrous oxide) is formed and finally when it is saturated, N_2 (di nitrogen, not a greenhouse gas) is produced. Also nitrogen is lost to the atmosphere through ammonia and ammonium but they are not greenhouse gases. This flow is shown on the right-hand side of Figure 3. Therefore the timing of fertiliser application may have a significant role in reducing nitrous oxide emissions.

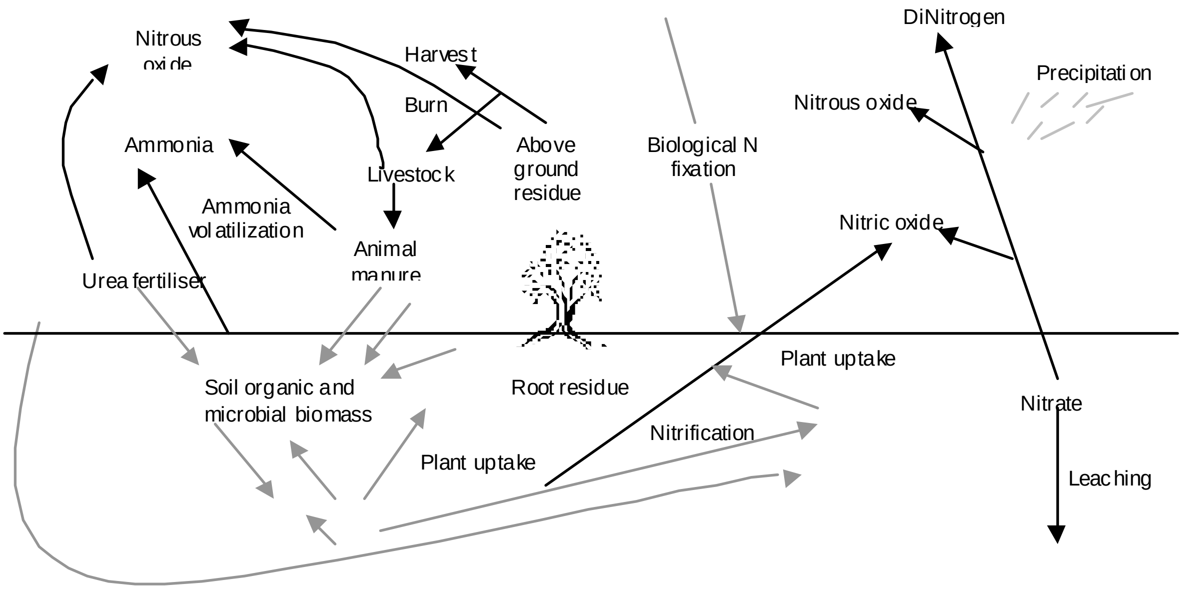

Figure 3. Nitrogen transformation in plants, soil and water (black arrows are the outflows, grey arrows are the inflows). (Source: Tisdale, S.L. and Nelson, W.L. *Soil fertility and Fertilisers 3rd Edition,* p 123.)

Not much is known about nitrous oxide emissions from the Land Management sector. Consequently no advice can be given with certainty, about which management practice is most effective in reducing emissions. Work being undertaken by the CRC in Greenhouse Gas Accounting will help identify the emission reduction methods that give the best results.

1.5 The National Greenhouse Gas Inventory

Australia has produced an annual inventory of national greenhouse gas emissions since 1990 as part of its commitments under the United Nations Framework Convention on Climate Change. The inventory provides a baseline to monitor and review response action and develop projections of greenhouse gas emissions. The 1999 National Greenhouse Gas Inventory, released in April 2001, provides the latest report on Australia's greenhouse gas emissions. The inventory includes improvements in data collection methods that have been used to update emission estimates in the 1990-1999 inventories.

The total emissions reported in the national inventory do not represent Australia's performance against the Kyoto Protocol. Guidelines for reporting on the Kyoto Protocol, including the 1990 baseline, are still being negotiated. For example, some parts of the land based emissions and sinks that are reported in the national inventory will not be included in reporting for the Kyoto Protocol.

The inventory reports on all human-induced greenhouse gas emissions in six sectors as established by the Intergovernmental Panel on Climate Change.

1. Stationary energy
2. Industrial processes
3. Transport
4. Agriculture
5. Land use change and forestry
6. Waste

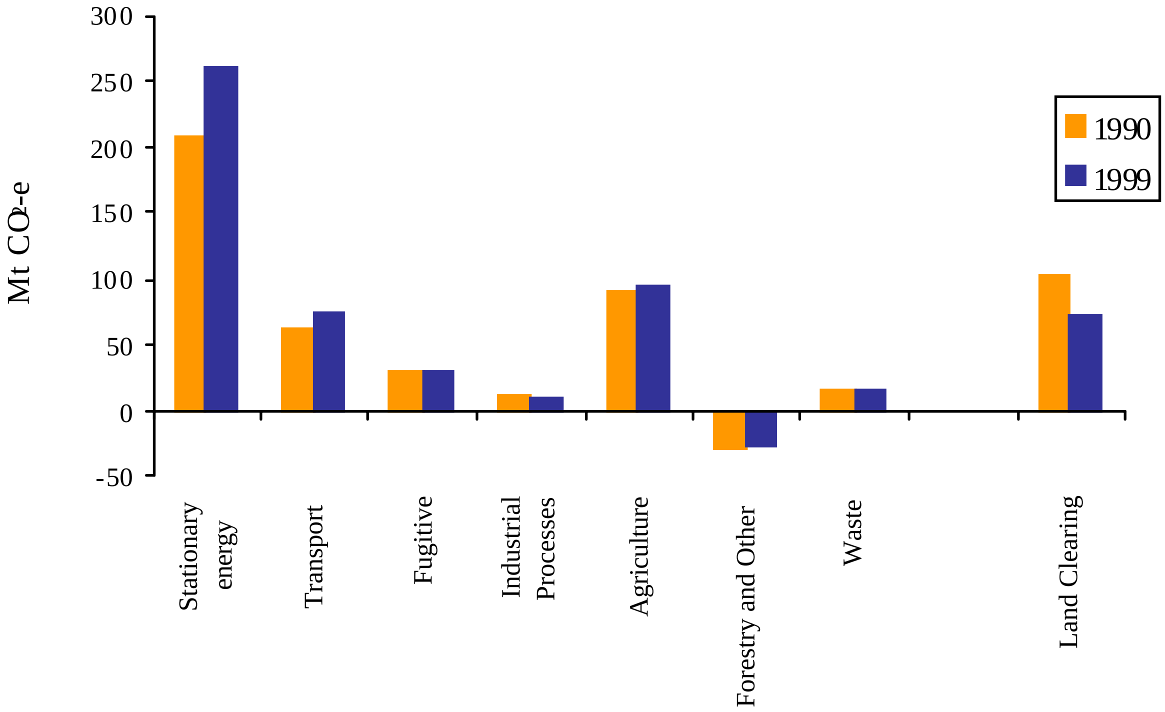

Figure 4. Greenhouse gas emissions by sector in 1990 and 1999 (Australian Greenhouse Office, 2001). (Source: AGO 2001.)

Figure 4 illustrates the combined agriculture, land clearing and forestry sectors are the second largest contributor to the Nation's greenhouse gas emissions, and are responsible for about one third of Australia's national emissions.

1.5.1 What is included in the National Greenhouse Gas Inventory agriculture sector?

Emissions of methane and nitrous oxide are included in the agriculture sector. Carbon dioxide emissions are not accounted for in agriculture as international inventory methodology assumes there is a net balance between uptake and emissions in crops and pastures, and for livestock. For example, with the burning of residues and savannas, methane and nitrous oxide emissions are estimated but not carbon dioxide. The assumption is that whatever carbon dioxide is released will be taken up in new crops and regrowth of pastures.

The agriculture sector does not include:

- Fuel use in agriculture and transport of agricultural inputs and products. Farm fuel is included in the Stationary energy sub-sector of Energy. Emissions from fuel use are thought to be relatively minor compared with other agriculture emissions. Hence the significant reductions in fuel use in WA associated with reduced tillage would not appear to have contributed greatly to reducing farm greenhouse emissions. Emissions associated with transport of agricultural inputs and products are included in the Transport sub-sector.

- The Land use change and forestry sector, including forest management, vegetation sinks, land clearing and soil carbon. Carbon dioxide fluxes are the main greenhouse gas involved. This sector continues to come under close scrutiny as 1990 land clearing emissions are crucial to the establishment of Australia's baseline for the Kyoto Protocol and because sinks will be a vital emissions offset mechanism. There has been considerable research into the greenhouse inventory methodology for clearing and plantation sinks, while relatively little has been done in relation to the methodology for carbon storage in agricultural systems.

The Department of Agriculture has compiled the following graph (Figure 5) outlining the split of emissions from the different agricultural activities. The graph demonstrates that the greenhouse gas emissions are predominantly from enteric fermentation and savanna burning.

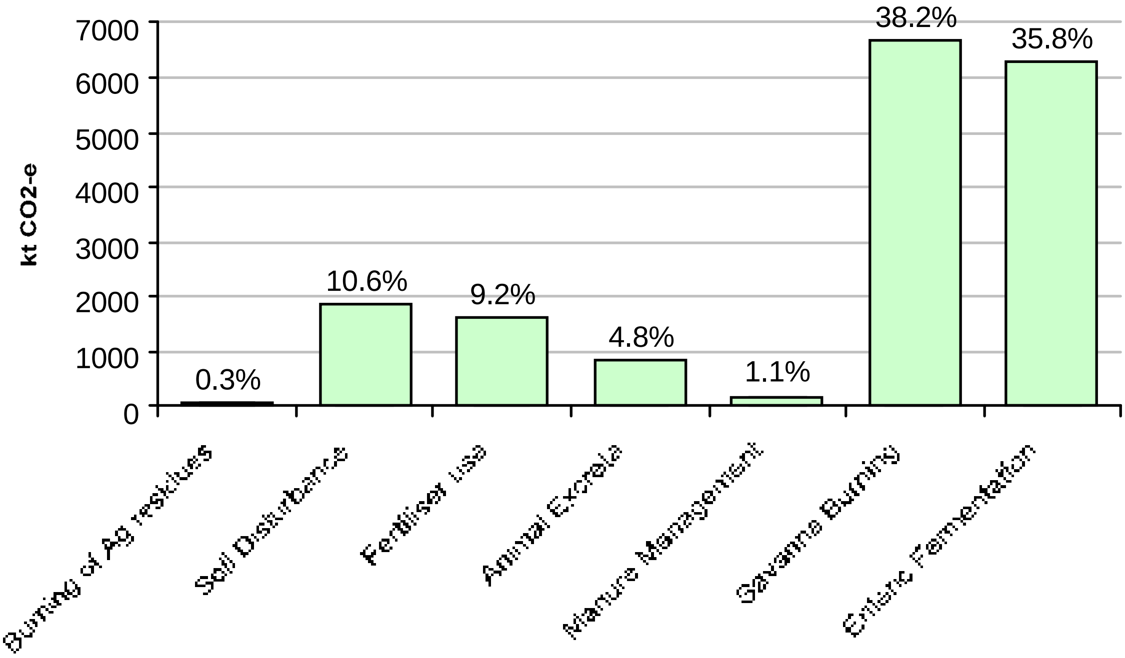

Figure 5. Sources of emissions from Western Australian agriculture (non-CO_2) gases as estimated by the Department of Agriculture for 1999. (Source Department of Agriculture, Western Australia.)

Figure 5 shows savanna and temperate grassland burning emissions largely account for both the relatively high contribution by agriculture to the State's emissions profile and to agriculture sector emissions growth. 1999 savanna burning emissions, sourced from the NGGI, account for 38 per cent of WA agriculture sector emissions. Nationally, savanna burning is only 14 per cent of agriculture emissions.

Areas burned (from 1997) are measured using satellite imagery and appear to greatly exceed previous estimates by fire authority experts. Emissions estimates are based on 10-year average figures for areas burned. Should earlier figures be revised after study of satellite images, savanna burning emissions estimates would show further substantial increases.

All fire scars are measured and attributed to agriculture, regardless of who or what started them. Only a small percentage of fires are for pastoral management. No account is taken of fires being started by lightning strikes, and other accidental or deliberate lightings.

The average fuel load used in the inventory for WA, 7.7 tonnes of dry matter per hectare, is strikingly higher than those used for the Northern Territory and Queensland (5.8 and 3.0 tonnes per hectare respectively) and is accordingly open to serious question. The fuel load used in the published 1995 WA inventory was 8.3 tonnes per hectare (the NT figure for 1995 was 4.1 tonnes per hectare). We do not know the basis for these revisions.

1.5.2 Limitations of the National Greenhouse Gas Inventory

Emissions from fertilisers, soils and burning are estimated using methods which do not account for such important variables as climate, soil type, management practices, fire intensity, composition of biomass being burnt, rainfall and so on. The methodology assumes emission rates are the same across the whole of Australia, even though Western Australia has a markedly drier climate.

There is an increasing need for an internationally and nationally recognised framework, including a methodology and systematic approach to ensure accounting methods do not result in disadvantaging (or advantaging) some States or regions over others.

2. WHAT GREENHOUSE MEANS FOR LAND MANAGEMENT AND CARBON SEQUESTRATION

A number of opportunities and threats for land management are arising from the greenhouse issue. With the Kyoto agreement has come speculation of the creation of carbon markets and what this can deliver to land managers. Yet greenhouse gas accounting has resulted in increasing scrutiny of agriculture and land clearing due to their high levels of greenhouse gas production coupled with a perceived poor environmental track record.

Land managers have two ways of responding to the greenhouse issue: acting as a carbon sink and reducing emissions.

2.1 Carbon sinks

What is a 'carbon sink' and how do they have a place in land management? A carbon sink is something that absorbs carbon from the atmosphere through biological processes. The boxes in Figure 2 represent sinks. The process of storing carbon in a sink is known as 'carbon sequestration'.

The Kyoto Protocol, the prime international agreement relating to the abatement of atmospheric greenhouse gas concentrations, provides that in some circumstances sequestered carbon can be considered to offset or compensate for emissions from fossil fuel use or other sources.

Australia is in a unique position with respect to sinks. It is the only Annex 1 (developed) country where emissions and sinks from terrestrial ecosystems make up a significant portion of the carbon account. Thus, sinks matter to Australia.

The Kyoto Protocol allows carbon sequestration credits to be traded internationally. This would allow countries and companies to offset their greenhouse emissions by investing in carbon sequestration and consequently being given carbon credits for this sequestration.

Even if Australia does not sign the Kyoto Protocol there are already indications that an internal carbon market will be established.

Western Australia's rangelands and cleared agricultural lands have a large potential for carbon storage through the establishment of forests, trees and other perennial vegetation and through changes in land management practices.

Large scale investment in revegetation of cleared farmland for carbon sink purposes will also have the effect of contributing to the fight against dryland salinity, land degradation and biodiversity loss.

There are considerable opportunities for this new market to support new rural industries and provide a broader base for rural economies and communities.

However the massive amounts of voluntary, landowner based revegetation works must not go unrecognised. Work undertaken of this type by groups such as Landcare groups and other non-government and community based organisations (as distinct from the commercial plantations) need to be accounted for as a greenhouse sink due to the emissions benefits arising from such land use change.

Coordination of much of this work is being done through the accredited Regional Natural Resource Management Strategies being required under the National Action Plan for Salinity and Water Quality (NAP). The strategies will form a framework for the majority of natural resource management activity in the regions.

2.1.1 Certainty of sink options

When considering terrestrial sink options the level of certainty needs to be considered.

The Kyoto agreement in Article 3[1] establishes two categories for carbon sinks: afforestation and reforestation, and the rest include sequestration in agricultural soils and in woody perennials in the rangelands.

Plantings that meet the following definitions could be eligible as afforestation or reforestation sinks under Article 3.3 of the Kyoto Protocol:

- a forest of trees with a potential height of at least 2 metres and crown cover of at least 20 per cent;
- in patches greater than 1 hectare in size;
- established after 1 January 1990;
- on land that was clear of forest at 31 December 1989 (not land that has been cleared since 1990); and
- established by direct human induced methods, i.e. planting or direct seeding, or human induced promotion of regeneration from natural seed sources.

In addition to afforestation and reforestation, a limited range of other carbon sink activities is included under Article 3.4 of the Kyoto Protocol. Article 3.4 activities relevant to land management are revegetation, salt land pastures, tree crops such as oil mallees (where these do not satisfy article 3.3 criteria), grazing land management, cropland management, improved pastures and rangeland management.

Soil management practices associated with grazing and cropping such as stubble retention, minimum tillage and reduced stocking have the potential to increase levels of carbon in the soil.

Countries ratifying the Kyoto Protocol must nominate by no later than 1 January 2007 which of the Article 3.4 activities they will account for during the first commitment period (2008-2012). Should Australia ratify the Kyoto Protocol, the Commonwealth Government would need to assess the costs and benefits for Australia before making a decision on whether to nominate any of these activities. Accounting for the carbon in these activities presents quite different challenges to those dealt with in Article 3.3 activities, and relatively little progress has been made.

The areas of uncertainty for Article 3.4 sinks are their actual ability to sequester and maintain carbon stores over the long term and, consequently, whether they should be considered as part of Australia's approach to greenhouse emissions abatement.

[1] See Appendix 1

2.1.2 Possible sink options for Western Australia

The different sinks that could possibly exist in Western Australia include:

- **Rangelands Management (Article 3.4).** Through revegetation, restoration, de-stocking and altered management in some rangeland areas there exists the potential to increase stored carbon in both soils and vegetation. The main risk associated with this practice is fire.
- **Wheatbelt Revegetation (Article 3.4).** There are strong synergies between revegetation and carbon sinks. A number of areas in the wheatbelt are degraded in one way or another. By selling the carbon credits of plants being used for revegetation activities the monies can be used as a revenue source for undertaking revegetation. However transaction costs relating to these small sink projects may restrict the market.
- **Saltland Pastures (Article 3.4).** The areas of saline land are steadily increasing. These areas traditionally go out of production, as the high levels of salt are prohibitive to traditional farming species. However there are a number of saltland pasture species available to keep these areas productive as well as trying to reduce further salinity.
- **Cropland Management (Article 3.4).** Increasing the levels of carbon in the soil has been identified as a potential carbon sink. It is suggested that altering soil management towards such conservation practices as no-till, will allow for an increase in soil carbon. There is however concern that the store may disappear very quickly with small changes in management.
- **Perennial Pasture Phases (Article 3.4).** With encroaching salinity, deep rooted perennial pasture species are being incorporated into farming systems. Being perennials these species are a possible carbon sink. As these plants will be grazed to ensure they are a profitable addition to the farm, the sink potential is largely restricted to their impacts on soil carbon levels. These plants will have relatively high growth rates when compared to salt land perennials.
- **Commercial Tree Farming (Article 3.3).** DCLM and FPC have already developed a number of different options to take advantage of the sink capacity of trees. A number of species have been identified as commercial trees crops, but are mainly centred in the State's south-west. These include oil mallees, blue gums and maritime pine.
- **New Plant Industries.** It is expected that there will be a number of new plant options adopted across Western Australia. The sink potential of these options is as yet unknown.

Appendix 4.2 shows tree sinks (softwoods, hardwoods and oil mallee) have the largest ability to sequester carbon and are also the most certain. There are established techniques for measuring carbon stored in trees and there has been extensive carbon modelling work undertaken in Australia following carbon pools. For this reason those forests meeting the 3.3 requirements are already having their carbon credits traded.

The levels of certainty for the other possible carbon sequestration activities are low. This is generally a reflection of limited research being undertaken on the carbon sequestration abilities of these sinks. To determine where to invest, future research consideration will need to be given to the potential of the sink to sequester carbon and a comparison of costs of the sink activity to activities already being undertaken on the land. The t in Appendix 2 has put together rough estimates for the possible carbon sequestration activities. However this preliminary analysis will need to be extended to properly assess the options. But it seems tree crops are and will be the best terrestrial sinks due to their certainty under Kyoto and their large capacity to sequester carbon.

2.1.3 Carbon sink risks

Although there are a number of benefits associated with sinks, the main being synergies with sustainability, there are a number of risks. These include:

1. Property rights to carbon sequestration are unclear.
2. Amount of carbon claimed, believed or projected to be sequestered is not actually sequestered due to:
   - natural causes: changed climate conditions;
   - mistake;
   - negligence;
   - fraud.
3. Transaction costs relating to carbon sequestration and rights accounting restrict the market. In particular, small sink projects at the individual landholder scale may not yield sufficient revenues from carbon credits to meet the transaction costs.
4. Carbon that has been sequestered and for which credits have been registered and sold becomes no longer eligible for credits.
   - Market rules change through market actions.
   - Market rules change through Government policy.
   - Market rules change through international agreements.
   - The financial context of carbon rights investments change.
5. The relative values of carbon rights fall in comparison with other investments, alternative options for greenhouse emission reductions or the cost of borrowing to invest in carbon rights.
6. For individual farming businesses placing a small area of land to trade carbon may not be economic due to the high transactions costs (measurement and verification) associated with such ventures. The development of carbon pools or cooperatives will allow producers to minimise transaction costs as well as risks.

2.2 Emissions reduction

For agriculture, the most obvious way of reducing emissions is through reducing clearing and methane emissions from animals. Nationally, emissions from land clearing provide a significant percentage of total greenhouse emissions. However in Western Australia, due to increasingly strong regulation of land clearing since 1987, this only contributes 2 million tonnes to the State's emission profile (less than 4 millionths of a per cent).

The majority of emissions reductions are expected to come from changes in land use and land management.

However choosing the most obvious may not necessarily deliver the greatest cost benefit outcome. The potential to reduce methane, nitrous oxide and carbon dioxide emissions is discussed below and is presented with more detail in Appendix 4.

2.2.1 Methane

Research is targeting organisms that produce methane in order to stop production at the source. CSIRO Livestock Industries has a major program underway to develop a vaccine that can be given to ruminants. Although the project is still not at the commercialisation stage, work with sheep inoculated with the vaccine has shown both a reduction in methane emissions coupled with a rise in productivity. There is also limited work going on in the use of feed additives for the intensive industries and finding other ways reducing ruminant methane emissions.

Until these products are commercially available, the major strategy for reducing methane production will be the same as the key profit driver for grazing: reducing the number of grazing days per kilo of product. However this sets up the dilemma of increased feed availability and therefore the temptation to increase stocking rates.

The difference in methane production between grazing systems can be substantial. On a daily basis the difference in methane emissions between animals in a well-managed feedlot against animals grazing poor sub-tropical pasture is a factor of nine.

Another option for Western Australia could be to limit the number of ruminants per property. However this will have the possible implications of decreasing profitability and farm diversity.

Other areas of possible methane reduction include swamps, wetlands and native fauna.

2.2.2 Nitrous oxide

Given the knowledge limitation there have still been a number of measures identified to manage nitrous oxide emissions including:

- optimising nitrogen inputs and application timing;
- improved drainage to reduce waterlogging;
- no-till farming, the main effect being to reduce soil mineralisation of nitrogen;
- banding fertiliser close to the root system of crops;
- stabilising nitrogen by maintaining crop residues;
- producing healthy, disease free crops with a balanced nutrient supply, particularly adequate supplies of phosphorous; and
- controlling timing and intensity of stubble burning.

These measures mostly depend on increasing the efficiency of nitrogen fertiliser use, rather than reducing application rates, as current rates are considered to optimise returns from land management industries.

There are also promising developments in controlled release and stabilised fertilisers that may have potential in the Land Management sector.

Given the minimal amount of information available, it is not known what management practices will have the best effect in reducing nitrous oxide emissions.

The National Greenhouse Gas Inventory (NGGI) only captures nitrous oxide emissions from nitrogen fertiliser application rates and background emissions from soils. Emission reductions, once quantified, from management changes such as those listed above are not captured by the NGGI. Changes such as these could be encouraged through Good Agricultural Practice (GAP) and Environmental Management Systems (EMS) and other accreditation systems.

2.2.3 Carbon dioxide

Although net carbon dioxide emissions from the agricultural sector are low and mostly not accounted in the Land Management sector by the NGGI, they can be further lowered through:

- decreasing areas of land being cleared;

- minimising unnecessary machinery use;
- changing to cleaner burning fossil fuels; and
- choosing bioenergy and biofuels over those produced from fossil fuels.

However carbon dioxide emissions are accounted for in the land use change and forestry sector with 2 million tonnes of carbon dioxide coming from land clearing. By reducing land clearing this annual figure can be reduced. See Appendix 4 for a scoping of emission reduction potential for terrestrial sources.

2.3 Climate change

Climate change is an important aspect of greenhouse for the Land Management sector. As the sector is biological, climate change will alter the types of products grown in certain regions. Responses to this are through adaptation. By understanding how climate change is predicted to occur, it gives guidance as to what the sector needs to do to ensure it remains viable in the long term.

CSIRO has used national and international computer models to simulate Australian climate patterns under conditions of increased CO_2 concentrations. The CSIRO Division of Atmospheric Research released the current scenario for Australia in May 2001. The following section summarises the findings for Western Australia.

Average annual temperatures are projected to rise by 0.4 to 2.0^{o}C by 2030 over most of Australia, with slightly less warming in coastal regions. By 2070, the increase would be from 1.0 to 6.0^{o}C.

Changes in temperature extremes are sensitive to changes in mean temperatures. Numbers of days above or below temperature thresholds change significantly, as shown in Table 1.

Table 1. Projected changes in the average number of days over 35^{o}C at Perth, and of days below 0^{o}C at Wandering for 2030 and 2070

Days > 35^{o}C	**Present**	**2030**	**2070**
Perth	15	16-22	18-39
Days < 0^{o}C	**Present**	**2030**	**2070**
Wandering	14	5-11	0-9

Autumn rainfall is projected to decline up to 20 per cent over south-west and southern WA. Winter rainfall is predicted to decrease by up to 20 per cent over much of WA. This pattern continues into spring. Thus rainfall is projected to decline over WA from autumn to spring - the main rainfall period for the south.

Evaporation rates are expected to increase with temperature. This leads to predictions of a decline in moisture balance over all of Australia.

The projected scenario needs to be considered in light of the significant climate change that has occurred over the past three decades in WA. The observed changes in rainfall and synoptic weather features (many of which have been documented in the work of the Indian Ocean Climate Initiative) illustrate the manner in which climate change has been manifested in daily weather events and seasonal trends.

- Greatest rainfall decline has occurred since the 1970s along the lower west coast, with decreases also observed in agricultural districts. Rainfall decline has been strongest early in the growing season (May-July). Trends in late season rainfall (Aug.-Oct.) have been small.

- Seasonal rains more likely to be below average, with the wettest third of seasons being less frequent.

- Fewer rain days in general, with a stronger decline in rainfall per rain-day. The proportion of growing season rainfall that comes from daily rain events of less than 10 mm has increased. Less rain comes from heavier daily rainfall amounts.

- Increased atmospheric pressure and El Nino events over the past 30 years but these changes do not explain the entire observed rainfall decline.

- Decreased frequency of cold fronts and increased incidence of high-pressure cells during winter. The lower atmosphere has become drier as a consequence.

- Mean winter latitude of the subtropical wind maximum (an indicator of the positions of the high-pressure belt) has moved southwards since 1975, suggesting a shift of climate zones.

- Unusual run of dry years when compared with historical records and also with computer generated 1000-years simulations of WA climate.

- Little trend in daily maximum temperatures, but there is a slight positive trend in daily minimum temperatures. Accumulation of chilling units is declining, while accumulation of heat units is increasing.

These events are consistent with current climate change projections for the areas affected. Rainfall decline is of similar magnitude but the timing is not, with the decline predicted to occur towards the middle of the 21^{st} Century, not at the end of the 20^{th}. It is also uncertain whether the predicted changes are additive to those that have already occurred.

The climate projections outlined above have implications for the Western Australian Land Management sector.

- *Declining length of growing season*
  The decrease in autumn rainfall implies that the start to the growing season would tend to be later than at present, while decreasing spring rainfall would tend to cut the season short (as in 2000 and 2002). Growth of southern rangeland pastures would also be affected.

- *Broadscale crop yield responses will vary according to region*
  The response of yields to climate change of broadscale crops is likely to show considerable regional variation. The drier parts of the cropping region already face yield limitations from lack of rainfall, and exhibit higher variation of yields from year to year. A continuing drying trend in May-Oct. rainfall would further reduce yields if not compensated by any increases in summer/autumn rain from tropical sources. Conversely, southern cropping districts experience yield limitations from waterlogging, and have generally lower inter-annual variability. A drying trend could improve yields as the incidence of waterlogging decreased. Similar regional variation would apply to annual pastures.

- *Yields increase under high CO_2 concentrations*
  A mitigating factor is that up to a warming of about $1^{o}C$, yields increase under higher CO_2 concentrations, even under declining rainfall. However, these benefits decline as warming continues, especially if rainfall decreases.

- Changes to growth characteristics of plantation species
  Changes in rainfall may alter the suitability of some areas for particular plantation species. Given the long rotation times of some species, this will require consideration well in advance.

- Large changes in heat or chill accumulation
  Rising temperatures have implications to the Land Management sector via potentially large changes in heat or chill accumulation and the frequency of temperature extremes. Those horticultural crops requiring vernalisation will likely face reduced cold accumulation. Tree crops are more sensitive to temperature trends because of the longer lead times associated with their establishment and development compared with annual crops. Adaptation will require a wider range of varieties to be available.

- Reduced risk of frost
  There have been no or small trends in extreme daily minimum temperatures during the last half of the 20th Century. Year to year variation in number of potential frost days is almost an order of magnitude. Frost risk will probably decline for larger warmings, but in the meantime the incidence may be maintained (or go up) if the frequency of clear sky conditions increases during spring. A critical factor will be the timing of frost events, and their combination with antecedent seasonal conditions (such as warmer winters that might not provide cold hardening for crops).

- Water supplies affected
  There is likely to be a major issue with water supply being affected by changes in the frequency and duration of runoff events. Rainfall changes since 1975 have seen not only a decline in seasonal totals and rainfall per rain-day, but also in the frequency distribution of daily rainfall amounts. As well, the number of wet winters (defined as decile 8 or above) has more than halved in the most recent 25-year period. Combined with higher evaporation rates, it is likely that the period between runoff events will increase.

- Rate of salinity spread expected to decline
  The rate of spread of salinity would be expected to decrease under a drier, more evaporative climate with fewer wet winters. However, groundwater rise in agricultural areas has generally continued through the period of recent rainfall decline. This suggests that recharge will continue to be dominated by land use options.

- Change in pest and weed risk
  The risk from insect pest and weed competition will probably change. Higher temperatures are favourable to many insects, though their ultimate activity will be dependent on any changes to summer rainfall. A warmer climate might also favour some plant diseases, but only if other factors are favourable (such as complementary seasonal conditions, sources of inoculum and suitable hosts).

- Reduced biodiversity
  Management of indigenous and remnant vegetation will have to face the possibility of extinction of many species that have a restricted range, especially where significant clearing has occurred. Recent studies on the potential change in distribution of some native plant species under greenhouse scenarios have shown the sensitivity of those species that have either a restricted natural range, or that are confined to remnant blocks and nature reserves.

- Climate change implications for trading partners
  The effect of climate change on overseas trading partners and competitors will possibly be just as significant as local climate change. Impact studies of

agricultural systems overseas show complex interactions between climate change scenarios and the yield and quality impacts. Yield increases are predicted for small amounts of warming, but they consistently decline as warming increases beyond a few degrees. Developing nations are considered more vulnerable as they often have less capacity to adapt. Projections of commodity prices are sensitive to the production and economic assumptions used in their modelling, but tend to rise with stronger climate impacts on agricultural production.

2.4 Opportunities

In discussing sinks the opportunity for carbon trading has been highlighted. However there are current opportunities arising from the greenhouse issue and others may emerge in the future.

2.4.1 Bioenergy

Bioenergy is an umbrella term for a wide range of energy products manufactured from plant sources. Bioenergy is essentially the processing of agricultural commodities into a fuel. The availability of raw material within Western Australia is critical to the establishment of local bioenergy industries.

Bioenergy has a role in future Australian energy supply scenario planning as it addresses many key strategic concerns of fossil fuels dependence. These include the following opportunities.

- Carbon neutral: Helping to alleviate a major contributor to greenhouse gas production.
- Domestically produced: Addressing balance of payments problems with increasing reliance on imported oil. Some export potential too.
- Renewable: Allowing much longer term planning of energy supplies.
- Less polluting: Many bioenergy products produce less emissions than competing fossil fuels. However this is not a universal attribute.
- Value adding: Most biological energy sources are manufactured from low value or waste agricultural and timber products, ensuring expansion of the local economy.
- Regional development: Agricultural production is decentralised. In many cases it is most economically viable to whole or partly manufacture the bioenergy close to the source of raw materials. New industry jobs for rural towns.

Specifications of the fuel change depending upon the intended use of the energy. For example, stationary electricity generation does not place a great deal of emphasis on the energy density of the fuel and handling/storage characteristics, as space and specialised handling equipment are usually available.

For the transportation sector however, the energy density and handling/storage characteristics are very important as fuel reserves range and the cost of modifications to existing or new equipment are key consumers concerns.

The more stringent the energy product's specifications, the higher the price of the fuel.

An overview of some technical and economic drivers of a bioenergy industry in WA is provided in Table 2.

Table 2. Overview of technical and economic drivers for bioenergy

Raw material	Supply potential	Bioenergy	Use	Techncial risk	Economic viability
Cereal starch	000 000s t	Ethanol	Petrol replacement: private transport	low	good
Cereal grain				low	poor
Cereal cellulose				high	excellent
Cereal cellulose	000 000s t	Direct combustion	Electricity generation	low	fair-good
Timber	00 000s t			low	fair
Oilseed grain	00 000s t	Biodiesel	Diesel replacement: industrial transportation	low	good
Animal fat	0 000s t			low	very good
Waste cooking fat/oil	000s t			low	excellent
Oil Mallee	00 000s t			high	poor-fair

3. SUGGESTED PRIORITY FOCUS AREAS FOR WESTERN AUSTRALIA

The information presented above details much of the complexity and breadth of greenhouse with respect to land management and carbon sequestration in Western Australia. As not every knowledge gap can be closed, a number of priority areas are suggested as requiring action. They are:

- expand the already successful and flourishing article 3.3 plantations, as carbon sinks;
- determining the potential of (Kyoto Protocol) Article 3.4 sink activities (cropland management, grazing land management and revegetation) to contribute to carbon sequestration in Western Australia;
- promote appropriate Kyoto Article 3.4 sink activities;
- assess how the 'Carbon Bank' initiative being investigated by the Greenhouse Taskforce could provide the Land Management sector with a major source of investment in greenhouse offsets and natural resource management;
- encourage the development of a bioenergy industry;
- review the current methodology for savanna burning and prepare a submission to the NGGI Steering Committee and the Australian Greenhouse Office requesting that the methodology for estimating emissions reflect the distinct differences in fuel load between the north and south of the State;
- promote methods to reduce methane emissions from ruminants, including improved grazing management and ruminant vaccination technology when it becomes available;
- continue involvement in current research determining baseline figures for emission levels from agricultural practices; and
- improve knowledge of climate change impacts on Western Australia through climate science and agricultural systems modelling.

Each of these points is discussed in more detail below.

3.1 Expanding article 3.3 plantations as carbon sinks

Western Australia has established a highly successful plantation program. The focus has been on supplying the wood market in a sustainable manner with plantation timber. However with the establishment of a carbon market it is hoped the plantation timber industry can be extended further.

Increasing the area of plantations has potential benefits including reducing the risk of salinity, improved water quality, increased farm profitability and developing a diversified industry base for regional communities. Although in some limited areas there is the possible disbenefit of reduced catchment water yield reducing fresh water availability.

Encouraging strategic establishment of plantations will provide benefits to farmers as well as manage the potential social issues associated with large areas of plantation.

3.2 Determining the potential of article 3.4 sinks

To maximise the possible environmental benefits the carbon market can deliver, it will be a priority to determine what other potential sinks will be able to store carbon in a way that is long term and not expensive.

A number of different sink options are presented in Appendix 2. The estimates put alongside the sinks are best estimates but are expected to act as a guide for determining which sinks warrant further investigation and investment to establish their feasibility as sinks in the carbon market.

The establishment of article 3.4 sinks in the carbon market will require research to determine the length, measurement, and certainty of sequestration. These factors have been already established for trees due to the strong correlation between wood sales and carbon storage. However for most of the 3.4 sinks such as saltbush pastures, soil carbon sequestration and rangelands vegetation, there has been no need to closely focus on carbon sequestered, as until now there has been no Australian market for the biomass stored in these sinks.

The benefits of these sinks being included in a carbon market include: guiding best management practice; financially rewarding farmers for implementing best management practices; increased areas of restored and revegetated bushland and increased sustainability of agricultural systems.

3.3 Promote appropriate article 3.4 sinks

After determining the potential of article 3.4 sinks, comprehensive cost benefit analysis including system benefits of different sinks in different locations will need to be undertaken. The outcome will be information for the State's community regarding their options with regard to establishing sinks themselves. A major benefit of promoting sinks to land owners and managers is the associated environmental services of maintained sinks including increased water quality, reduced erosion and maintained biodiversity.

3.4 Assess how the 'Carbon Bank' initiative could provide the Land Management sector with a major source of investment in greenhouse credits and improved natural resource condition

Carbon is becoming a tradable commodity that provides natural resource management benefits as an externality. Due to the multiple natural resource management outcomes terrestrial sinks can deliver it is in the State's interest to encourage carbon sink investment, especially in areas that are not yet recognised by the international carbon trade market. This would include many of the article 3.4 sink options.

Through an initiative like the 'Carbon Bank', the State Government could collect revenue as payment for the establishment of sinks. The State Government could then contract landholders to establish both Article 3.3 and 3.4 sinks to provide the State with the paid for carbon credits. An important additional benefit is that funds collected and used in this way could be used as additional matching funds for the National Action Plan on Salinity and Water Quality (NAP) and strategically applied through Regional NRM strategies.

3.5 Encouraging the development of bioenergy industries

As much of the greenhouse gases produced come from the use of fossil fuels as an energy source, there is great potential for the State to reduce its greenhouse gas emissions through encouraging bioenergy industries. For accounting purposes, bioenergy produces fewer greenhouse gases. This is because the carbon dioxide released is considered to be equal to the carbon dioxide sequestered in the plant. For instance, it is estimated biodiesel produces 75 per cent less accountable greenhouse emissions than diesel.

Bioenergy is generated from plant biomass. For the Land Management sector, the use of residues from wood processing, canola oil for biodiesel and crop stubble may all provide base stocks for energy generation.

To develop bioenergy industries the State Government can provide incentives through a number of policy mechanisms, as well as direct funding. This needs to be factored into the proposed bioenergy industry development strategy.

Benefits of increased bioenergy use include: cleaner burning fuel and reduced air pollution; reduction in State greenhouse gas emissions; diversified industry base for both farmers and regional communities; and possible secondary environmental benefits.

3.6 Review the current methodology for savanna burning

Savanna and temperate grassland burning emissions largely account for both the relatively high contribution by agriculture to the State's emissions profile and to agriculture sector emissions growth. 1999 savanna burning emissions, sourced from the NGGI, account for 38 per cent of WA agriculture sector emissions. Nationally, savanna burning is only 14 per cent of agriculture emissions.

The average fuel load used in the inventory for WA, 7.7 tonnes of dry matter per hectare, is strikingly higher than those used for the Northern Territory and Queensland (5.8 and 3.0 tonnes per hectare respectively) and is accordingly open to serious question. The fuel load used in the published 1995 WA inventory was 8.3 tonnes per hectare (the NT figure for 1995 was 4.1 tonnes per hectare). The basis for these revisions will be reviewed and amended if necessary.

3.7 Develop and promote methods to decrease methane emissions from ruminants

Ruminants produce 1 in every 7 tonnes of Australia's greenhouse gas emissions, and close to 40 per cent of Western Australia's agricultural sector emissions.A huge reduction could be made in the State's emissions by reducing the emissions from ruminants through management practices, and anti-methanogen technology.

CSIRO has already set a contract with the Australian Greenhouse Office specifying an abatement of 1.53 mega tonnes of carbon dioxide equivalents between 2008-2012. At a 20 per cent emissions reduction, this will mean about 1.3 million sheep and 1.1 million cattle need to be vaccinated.

To ensure this target can be met the Department of Agriculture should play a lead role in the promotion of anti-methanogen technology and management practices.

3.8 Continue involvement in current research determining baseline figures for emission levels from agricultural practices

As there is so much uncertainty surrounding where emissions come from and the magnitude of these emissions particularly in regard to nitrous oxide, it is in the State's interest to remain involved in research aiming to clarify many of the questions surrounding greenhouse emissions.

By establishing such baselines as to the sources and magnitude of emissions, Good Agricultural Practice guidelines can be developed. Without this information it is hard to assess which management practices achieve the best, combined outcome in emissions reduction.

3.9 Improve knowledge of climate change impacts on Western Australia through climate science and agricultural systems modelling

There are two complementary areas of research. The first is the need to improve the confidence of the climate change projections, especially for variables such as rainfall, and at local spatial scales. This means improvements to the global ocean and atmosphere models that are our major tool for investigating atmospheric and oceanic responses to changing greenhouse gas concentrations. In particular, better information is required on:

- more accurate climate simulations - trends, seasonal distribution, extremes;
- improved ability to attribute climate changes to synoptic weather patterns;
- greater spatial resolution;
- inter-model comparisons of climate change for WA; and
- biophysical/production impacts.

The Indian Ocean Climate Initiative (IOCI) has been a model for cooperative funding of climate research, combining WA Government departments and agencies with the Bureau of Meteorology and CSIRO. It has studied the nature of climate change and variability experienced over the past three decades, plus it is currently investigating the potential for improved seasonal forecasting. It is important the State continues to support the work of IOCI.

The second area of research is defining possible impacts of climate change on land management systems such as broadscale cropping, plantations, horticulture, pastures and animal industries, including the responses of plant and animal diseases, and of insect pests. Quantifying possible impacts of climate change on the land use management sector provides information as to the scope for mitigation and will identify key adaptation issues that require action now. There is also a demand for better information on future climate from several land-use planning initiatives that have been recently established. Key areas within this area of study are as follows.

- Economic responses in Australia and internationally.
- Impacts on resource allocation and sustainability.
- Capacity to adapt to climate change.

It is suggested a project of this nature draw on the experience of industry specialists in assessing likely impacts, sensitivities and potential for adaptation mitigation and new industries. The project will summarise the state of knowledge and identify gaps for further research. Outputs can be reports on how industries have responded to climate change already experienced as well as impacts from future change.

These actions have a number of inter-dependencies allowing for them to be combined to form two integrated initiatives on greenhouse emissions abatement for the Land Management sector.

1. Using integrated, whole-farm enterprise responses to develop Good Agricultural Practice (GAP) protocols.

   By deepening the understanding of emission sources and climate change impacts for the Land Management sector, the information can be fed into developing frameworks for Good Agricultural Practice. Increasing knowledge in the area of baselines will mean appropriate and informed decisions can be made regarding which practices result in reduced emissions.

   Good Agricultural Practices will also involve the management of, or restoration of, native vegetation, with this sort of activity using 3.4 sinks receiving carbon credits. With adequate quality assurance GAP can thus be used as a guide to voluntary actions, compliance with target reductions and with rules in relation to sink establishment.

2. Development of policies that encourage the establishment of terrestrial carbon sinks in a manner that achieves natural resource management outcomes.

   Developing a 'Carbon Bank' initiative allowing for Article 3.4 sinks to be recognised as a tradable sink at the State level at least, as well as expanding existing plantations has the possibility of achieving natural resource outcomes. Through thoughtful policy creation and application, sinks will offer Western Australia the opportunity to restore, maintain and improve natural resources. Importantly there are opportunities to match these funds, dollar for dollar, with Commonwealth funding programs under the NAP and NHT2.

4. APPENDICES

Appendix 1: Extract from Article 3 in the Kyoto Protocol

Taken from: http://unfccc.int/resource/docs/convkp/kpeng.html

3. The net changes in greenhouse gas emissions by sources and removals by sinks resulting from direct human-induced land-use change and forestry activities, limited to afforestation, reforestation and deforestation since 1990, measured as verifiable changes in carbon stocks in each commitment period, shall be used to meet the commitments under this Article of each Party included in Annex I. The greenhouse gas emissions by sources and removals by sinks associated with those activities shall be reported in a transparent and verifiable manner and reviewed in accordance with Articles 7 and 8.

4. Prior to the first session of the Conference of the Parties serving as the meeting of the Parties to this Protocol, each Party included in Annex I shall provide, for consideration by the Subsidiary Body for Scientific and Technological Advice, data to establish its level of carbon stocks in 1990 and to enable an estimate to be made of its changes in carbon stocks in subsequent years. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall, at its first session or as soon as practicable thereafter, decide upon modalities, rules and guidelines as to how, and which, additional human-induced activities related to changes in greenhouse gas emissions by sources and removals by sinks in the agricultural soils and the land-use change and forestry categories shall be added to, or subtracted from, the assigned amounts for Parties included in Annex I, taking into account uncertainties, transparency in reporting, verifiability, the methodological work of the Intergovernmental Panel on Climate Change, the advice provided by the Subsidiary Body for Scientific and Technological Advice in accordance with Article 5 and the decisions of the Conference of the Parties. Such a decision shall apply in the second and subsequent commitment periods. A Party may choose to apply such a decision on these additional human-induced activities for its first commitment period, provided that these activities have taken place since 1990.

Appendix 2: Scoping of sink potential for terrestrial sinks

Industry (horticulture, rangelands, broadacre and animal industries)	Carbon sink	Where in state possible	Gross target area (million ha)	Projected area of land use change (ha)	Average carbon sequestered (tCO2e/ha/yr)	Range of CO2e benefit 2008-2012 (tCO2e)	Total carbon over 30 years (tCO2e/ha)	Range of expected costs	Collateral benefits	Risk/certainty under Kyoto Protocol	Other risks	Implementation issues including verification	Information source
Broadacre - vegetation sinks	Hardwood/ Bluegums*			266,308	103	19,990,000			Reduced salinity risk, improved water quality, increased farm profitability and developing a diversified industry base for regional communities.	Certain (3.3)	Fire, pests and disease	Good models predicting C stores in trees developed.	FPC (See Appendix 3)
	Hardwood/ Eucalyptus sawlogs*			34,810	100	1,234,000			Reduced salinity risk, improved water quality, increased farm profitability and developing a diversified industry base for regional communities.	Certain (3.3)	Fire, pests and disease	Good models predicting C stores in trees developed.	FPC and CALM (See Appendix 3)
	Softwood/ pinaster & radiata*			158,101		7,631,000			Reduced salinity risk, improved water quality, increased farm profitability and developing a diversified industry base for regional communities.	Certain (3.3)	Fire, pests and disease	Good models predicting C stores in trees developed.	FPC (See Appendix 3)
	Landcare plantings			1,750,000	40-60								
	Oil mallees	Low to medium rainfall areas	up to 3		15 (but up to 30). This is annual above ground growth rate.	15,500,000		If prototype testing of integrated processing at Narrogin is successful and when large volume harvest systems are refined then this activity could be economically viable in its own right. This should become clear on 2003.	Regional econ development, local salinity control.	It depends on how the oil mallee is grown. It is possible for oil mallees to be either 3.3, or 3.4.	Fire, pests and disease		J. Bartle CALM
Broad Acre	Cropland management - agricultural soils	Low to medium rainfall	12	1,200,000	Approximately 4 t/ha	1,000,000	24,000,000	Unknown	Improved soil condition, reduced wind and water erosion, possible increased yield.	Uncertain (3.4)	Disease associated with stubble retained.	Verification of implementation should be available through ABS stats.	R. Harper CALM and N. Shocknecht DAWA
	Perennial pastures/forages (lucerne)	medium rainfall	6	2,000,000	1	500,000		Est. main and harvest ($80/ha)	Salinity management	uncertain (3.4)	Market decline for livestock. Sink permanancy. If used in phase farming the sink exists for 3-5 years at a time. Not neccesarily a permanent stand.		R. Latta. DAWA

Appendix 2: Scoping of sink potential for terrestrial sinks continued (page 2 of 2)

Industry (horticulture, rangelands, broadacre and animal industries)	Carbon sink	Where in state possible	Gross target area (million ha)	Projected area of land use change (ha)	Average carbon sequestered (tCO2e/ha/yr)	Range of CO2e benefit 2008-2012 (tCO2e)	Total carbon over 30 years (tCO2e/ha)	Range of expected costs	Collateral benefits	Risk/certainty under Kyoto Protocol	Other risks	Implementation issues including verification	Information source
Broadacre cont..	Perennial pastures/forages (Tagasaste)		1	100,000.0	1.6			$1000/ha	Increased profitability, stocking rate. Decreased recharge, wind erosion.	Uncertain (3.4). No extensive research on tagasaste and its ability to store carbon biomass.	Possible failure associated with adopting a new type of pasture unlike others.		
	Saltland pastures												
Rangelands	Vegetation	Southern Rangelands			0.5-1.0 The amount of biomass that is removed by cattle is less than 10 per cent. Therefore cattle management will have little effect on making the rangelands a better sink. Termites and other invertebrates remove about 50 per cent of the biomass, and ferals eat an unknown portion.				Possible flow-on benefits into the area of environemntal management. i.e. stabilisation and regeneration of ecosystems.	Uncertain (3.4) work is being undertaken in this area.	Not sure how rangelands will respond to management changes, e.g. destocking, grazing manipulation, re-establishmnet of pastures on scalds.	Difficulty to measure, and possible difficulty in sequesting.	R. Harper CALM
	Soil carbon	Southern Rangelands					5.5 t/ha		Possible flow on benefits into the area of environemntal management. i.e. stabilisation and regeneration of ecosystems.	Uncertain (3.4) work is being undertaken in this area.	Not sure how rangelands will respond to management changes, eg destocking, grazing manipulation, re-establishmnet of pastures on scalds.	Difficulty to measure, and possible difficulty in sequesting.	R. Harper CALM
Horticulture	Soil carbon	South West and areas where irrigation is possible	0.03	7,500	8	10,000 to 112,000	25,000 to 280,000	$300 to $2000	increased efficiency of fertiliser, irrigation and pesticide use.	Uncertain (3.4)	Failure to increase soil C to potential levels.		B. Paulin DAWA
Intensive animal industries													
Other	Wood products				Already sequestered in the trees - adds to the length of the C store and capacity of the trees to store C in accounting methodology.				Possible taxation mechanisms favouring products that act as a C store.	Uncertain. Currently not included in Kyoto.		Work being undertaken to determine lifecycle of different wood products to allow for their inclusion as a C stock.	

Appendix 3: Supporting information for the Western Australian Greenhouse Strategy – Contribution of Western Australia's plantation estate to carbon sequestration

20 December 2002

Prepared by: Peter Ritson and Bruce Brand, Department of Conservation and Land Management; and Ian Herford and Luke Morgan, Forest Products Commission.

Year	Hardwood/ bluegums (ha)	Hardwood/ eucalypt sawlogs (ha)	Softwood/ pinaster & radiata (ha)	Estate increase per year (ha)
1990-1994	26,661		10,521	37,182
1995	9,677		372	10,049
1996	20,182		803	20,985
1997	22,250		1,381	23,631
1998	23,400		2,050	25,450
1999	27,500		3,700	31,200
2000	59,715	130	4,926	64,771
2001	19,123	200	4,118	23,441
2002	9,800	480	1,030	11,310
2003	6,000	1,000	3,800	10,800
2004	6,000	2,000	7,600	15,600
2005	4,500	3,000	11,400	18,900
2006	4,500	4,000	15,200	23,700
2007	4,500	4,000	15,200	23,700
2008	4,500	4,000	15,200	23,700
2009	4,500	4,000	15,200	23,700
2010	4,500	4,000	15,200	23,700
2011	4,500	4,000	15,200	23,700
2012	4,500	4,000	15,200	23,700
Total hectares	**266,308**	**34,810**	**158,101**	**459,219**

Total carbon sequestered 2008-2012

Bluegum	19,990,000 tonnes CO_2-e
Eucalypt sawlogs	1,234,000 tonnes CO_2-e
Softwood	7,631,000 tonnes CO_2-e
Total	**28,855,000 tonnes CO_2-e**

Notes on estimation of carbon sequestration

General

Assumes short rotation plantation conditions specified in the Marrakesh Accords (i.e. 'For the first commitment period, debits resulting from harvesting during the first commitment period following afforestation and reforestation since 1990 shall not be greater than credits accounted for on that unit of land').

Assumes replant after harvest.

Plantations established between 1990 and 1994 (aggregate figures) all assumed to be 1993 plantings to account for increasing rate of establishment over the period.

Eucalypt sawlogs

MAI = 8 m^3/ha/yr stemwood.

Vol. growth curve (for *E. saligna*) from Moore/Hingston.

Applied data on carbon content of *E. globulus* trees to the *E. saligna* trees. Both species in bluegum group of eucs. Should be reasonable indication.

The 25 year rotational length of eucalypt sawlogs will not influence either Kyoto commitment period.

The model for plantings includes a 70 per cent thinning at age five with decay of thinnings modelled on the basis that they are not converted to products but left to decay naturally on site.

It is assumed that the biomass to stemwood ratio is similar to that of bluegum given there is no real data on this.

Decay rates are based on national 'All Eucalypt species' averages.

The decay rates of sawlog species have been set to just below those of bluegum because of wider tree spacings coupled with the fact that trees are thinned at such an early age (younger tissues are prone to faster decay).

Bluegums

MAI = 17 m^3/ha/yr of stemwood.

12 year rotation.

1 year between harvest and re-plant.

Vol. growth curve derived by Ritson (derived from stem analysis of 59 trees from high- and low-productivity sites throughout the south-west). Should be reasonable indication.

Softwoods

MAI = 15 m^3/ha/yr of stemwood.

Assumes carbon sequestration is the same in *Pinus pinaster* and radiata; and one year between harvest and replant.

Source and explanation of plantation estate figures

Note:

- The figures from 2003 to 2012 are estimates only.
- Figures for bluegums assume on-going plantings by some private investors.
- Figures for eucalypt sawlogs and pines are based on an expected four foldincrease in plantings by the Forest Products Commission.
- 1990 to 2001 figures sourced from National Plantation Inventory's (NPI) 1997, 2000 and 2002 tabular reports.
- 2000 and 2001 bluegum figures are total NPI figures minus the Forest Products Commission's (FPC) eucalypt sawlog figures.
- 2000 eucalypt sawlog figure is from the FPC's 2000 – 2001 Annual Report, Highlights.
- 2001 eucalypt sawlog figure is from information provided by FPC. Paper prepared for the Commonwealth on role of tree farming in relation to managing salinity and water quality.
- 2002 to 2012 figures provided by the FPC. 2003 to 2012 are estimates only.
- Proposed FPC plantings of pines and eucalypt sawlogs for 2003 cover approximately 5000 hectares with plantings estimated to increase to 20,000 hectares by 2006. Requires fourfold increase in current plantings.
- Therefore for FPC softwoods:

-	maritime pine 2003	3,400 ha	in 2006 will be	13,600 ha
-	radiata pine 2003	400 ha	in 2006 will be	1,600 ha
		,800 ha		15,200 ha

And for FPC hardwoods:

-	Eucalypt sawlogs 2003	1,000 ha	in 2006 will be	4,000 ha

- 2002 bluegum plantings cover approximately 9800 hectares. Based on figures from:
  - Pinetech
  - ITC
  - Hansol
  - BTP
  - APFL
  - Timbercorp
  - Great Southern Plantations
- 2003 and 2004 bluegum figures total 6000 hectares based on estimates from:
  - ITC
  - Hansol
  - APFL
  - Timbercorp
  - Great Southern Plantations
- Bluegum plantings are expected to decrease to 2008.
- Figure reduces to 4500 hectares from 2005 onwards as some plantings cease.
- Carbon sequestration in harvested products (mainly paper and timber) was not counted, i.e. assumed all carbon in harvested material emitted as CO_2 immediately.

Appendix 4: Scoping of emission reduction potential for terrestrial sources

Industry	Management practice	Where in State possible	Gross target area (million ha)	Projected area of management change (ha)	Average emission reduction (tCO2e/ha/year)	Range of CO2e benefit 2008-2012 (tCO2e)	Range of expected costs	Collateral benefits	Risk/certainty under Kyoto Protocol	Other risks	Implementation issues including verification	Information source
Rangelands and temperate grasslands	Fire management	Kimberleys			Not sure. Reliant on gas composition of burn.	Could be quite high as savannah burning contributes a significant amount to WA's total GHG emissions.			NGGI figures need to verified for WA. Work is needed to determine fuel loads, emissions from burn.	Need to determine what part of these emissions are contributed by the land management sector.		A. Craig DAWA
	Energy use efficiency	Southern rangelands and the Kimberley				Use of solar - small benefits expected.					Solar units being stolen.	
	Improved pasture utilisation	Southern rangelands and the Kimberley				Increasing the quality of the animals' diet maintains stocking rate and increases animal efficiency. Work is being undertaken to determine the feed quality in the rangelands. Figures on what is being eaten will be used in the NGGI and for pasture manipulation.						A. Craig DAWA
Broadacre/ Forestry and land management	Renewable transport fuels - biofuel (ethanol)	Agricultural cropping areas	6	1,000,000	1 Mha (1 t straw/ha)X 40% conversion = 400,000 t ethanol $x10^9$ litres = $1 X 10^9$ kg CO_2.	The benefits will be the amount of carbon dioxide released per litre of oil based fuel. Approximately 2 kg of CO_2 is produced per litre of petrol burned.	$60/t freight, $30/t organic matter and nutrients.	Cash from revenue, weed seed capture.		Nutrient deficiencies, greater acidification from product removal requiring more lime to be applied, declining organic matter and soil strucutre, soil erosion.	Infrastructure for regional conversion of cereal biomass to fuel.	M. Dracup DAWA

Appendix 4: Scoping of emission reduction potential for terrestrial sources continued (page 2 of 3)

Industry	Management practice	Where in State possible	Gross target area (million ha)	Projected area of management change (ha)	Average emission reduction (tCO2e/ha/year)	Range of CO2e benefit 2008-2012 (tCO2e)	Range of expected costs	Collateral benefits	Risk/certainty under Kyoto Protocol	Other risks	Implementation issues including verification	Information source
Broadacre/ forestry and land management	Renewable transport fuels - biodeisel		0.02		Each tonne of biodiesel used saves 2.5 t of CO_2 being released from fossil fuels.		$200/t	Possible decrease in NxO released into atmosphere as canola decreases root disease and sources N from a greater depth.		Market and seasonal risks.	Adoption rate of biodiesel is dependent on taxation polcy and is difficult to predict. Tax policy, regional dvelopment and better varieties the key to the crop making a significant reduction to overall greenhouse gases.	P Carmody DAWA
Broadacre	Anti-methanogen technology	Across all areas of State (ag and rangelands)		1.3 million sheep 1.1 million cattle	20% reduction in methane emissions.	1.53 Mt CO_2 equivalent.	Unknown	3% gain in productivity.		Cost of vaccine may inhibit adoption.		S. Gheradi DAWA
	Lime	Mainly SW Ag. Region			0.44 t CO_2/t lime/year.		Loss of production if reduce N application.			If lime is not applied, soil is not productive.		B. Bowden DAWA
	Nitrogen fertiliser management	Mainly SW Ag. Region			N emissions from fert. unknown.		Loss of production if reduce N application.			If lime is not applied, soil is not productive.		B. Bowden DAWA
	Nitrogen fixing pastures	South West Ag. Region	16	4,000,000			$20-50/ha	May decrease rates of soil acidification although offset by N fertilisers.		Decrease in legumes reflected in decreased soil fertility, decreased animal production, higher N fert. application for grain crops and grass pastures.		C. Revell DAWA
	Improved pasture utilisation (grazing)											

Appendix 4: Scoping of emission reduction potential for terrestrial sources continued (page 3 of 3)

Industry	Management practice	Where in state possible	Gross target area (million ha)	Projected area of management change (ha)	Average emission reduction (tCO2e/ha/year)	Range of CO2e benefit 2008-2012 (tCO2e)	Range of expected costs	Collateral benefits	Risk/certainty under Kyoto Protocol	Other risks	Implementation issues including verification	Information source
Broadacre cont…	Energy use efficiency - controlled traffic		8	2,000,000	0.4 kg CO_2 equiv/ha	800,000 t CO_2 equiv per year		Reduced compaction, feriliser use, herbicide use. Other management techniques associated with precision ag would further increase savings.	3.3 for fuel, N_2O emissions are uncertain.		Extension, capital costs of conversion. Verification of fuel and fertiliser savings would be relatively straight forward. But N emissions are uncertain.	M. Dracup DAWA
Horticulture	Composting organic wastes	South West and where irrigation is possible	0.03	7,500	123,600 t/yr		$300-2000/h/yr	sustainable reuse of organic wastes from ag and urban sources				B. Paulin DAWA
	Nitrogen fertiliser management	South West and where irrigation is possible	0.03	7,500	Emissions from fertilisers - unknown.	Emissions from fertilisers - unknown.	$300-2000/h/yr					B. Paulin DAWA
	Energy use efficiency											
	Renewable energy fedstocks											
	- plantation biomass											
Animal Industries	Dairy management	Dairies	0.1 to 0.15	100,000		Information not available						D. Windsor DAWA
	Excreta management											D. Dsouza, contacted, followed up, no response yet.