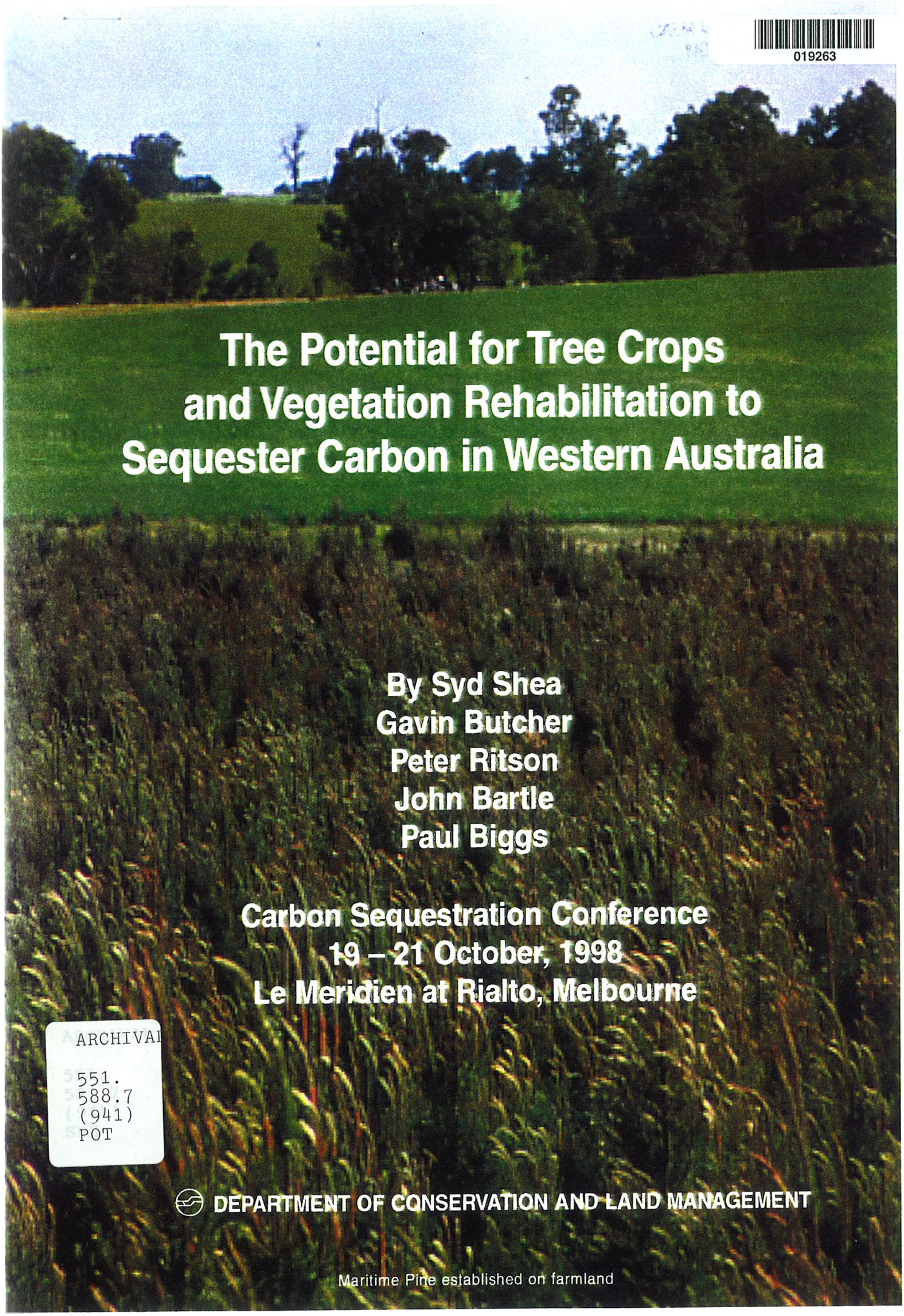

# The Potential for Tree Crops and Vegetation Rehabilitation to Sequester Carbon in Western Australia

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DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

Maritime Pine established on farmland

## Introduction

The concern about the potential for global warming resulting from the continued increase of greenhouse gas concentrations in the atmosphere has resulted in it becoming a powerful political and trade issue. Carbon stored in organic matter constitutes one of the world's major carbon pools and the destruction of forests primarily because of its conversion for agricultural uses and the absence of appropriate fire management regimes accounts for between 20-30 per cent of anthropogenic $CO_2$ emissions, (Houghton 1991). Large scale reafforestation to form an additional biosphere sink to compensate for input into the atmosphere by the burning of fossil fuels was proposed two decades ago (Breuer 1979). It has been estimated that up to 500 million hectares of tree plantations would be required to absorb the estimated annual increment of 2.9 billion tonnes of carbon. (Sedjo 1989).

The 1997 Kyoto Protocol of the 1992 Framework Convention on Climate Change, however, means that carbon stored in trees may have a real commercial value. Over the last decade several tree planting and forest rehabilitation schemes which have been designed to sequester carbon have been initiated, but the scale and number of schemes have increased markedly subsequent to the signing of the Protocol with the average price paid for carbon sequestered rising to $US12 per tonne (Costa 1998). The key features of the Protocol as they relate to carbon sequestration are:

- differentiated greenhouse gas emission targets for countries reflecting their individual circumstances;
- a collective target for developed nations of five per cent reductions in annual average emissions from 1990 levels during the first commitment period;
- activities that remove carbon dioxide from the atmosphere, or "sinks" such as tree planting, can be used to meet target commitments;
- credits gained from carbon sinks can be traded.

Australia's permitted greenhouse gas emission level is 108 per cent of 1990 emission levels. The 1990 inventory levels have not been finalised, but if it is assumed that emissions were approximately 500 million tonnes of $CO_2$, then Australia's permitted growth in $CO_2$ emissions is approximately 40 million tonnes. Proposed resource projects in Western Australia alone are projected to have emissions which approximate Australia's permitted growth in $CO_2$ emissions. Consequently, even though Australia was successful in negotiating a higher emissions target than most other developed economies, it will be difficult in the time available before the first assessment to meet the national target emission level.

Western Australia, probably more than any other developed economy, is disadvantaged by the targets set by the Kyoto Protocol because of the energy intensive nature of its economy. But the State does have the capacity to sequester large quantities of carbon over a relatively short time-period. This paper outlines the potential for carbon sequestration in Western Australia and the approach that is being taken to develop carbon sequestration strategies which minimises risks and costs by integrating carbon sequestration objectives with other beneficial environmental and economic goals.

## Carbon Sequestration – Science and Governance

The science that underpins the use of carbon sequestration to reduce carbon dioxide concentrations in the atmosphere is relatively simple. Plants absorb 3.7 units of $CO_2$ during photosynthesis to produce one unit of carbon stored in plant tissue. In perennial plants this carbon remains removed from the atmosphere for varying lengths of time.

The Kyoto Protocol recognised that carbon sinks could be used to offset emissions. Kyoto Protocol sinks are defined in article 3.3 – "... *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... ".*

Under current international rules for the first commitment period (2008-2012) the amount of carbon sequestered by trees will be determined by measuring the total carbon stocks in tree plantations established post 1990 in 2008 and again in 2012, and determining the average annual sequestration rate for the period. Any changes in carbon stocks between 1990 and 2008 are not taken into account. The sink value is added to the assigned amount (in the case of Australia 108 per cent of 1990 emission levels) which gives the sink a value equal to an emission in the first commitment period. It is assumed there will be subsequent periodic commitment periods.

There is considerable uncertainty about the rules governing carbon sequestration. For example, the definition of forests, reafforestation, deforestation and afforestation and the treatment of forest residues and the carbon in wood products is unresolved. Article 3.4 provides for the possible inclusion of other sinks, such as those found in agriculture soils and in pastoral (rangeland) areas. All these issues are the subject of current negotiations in international forums.

The outcome from these negotiations will have a major impact on the size of carbon sinks that could be credited. For example, the inclusion of carbon sinks formed by rehabilitation of the pastoral (rangeland) land would significantly increase the potential carbon sink in Western Australia because of the large areas involved. Recognition of the contribution that wood products make to reducing or ameliorating directly $CO_2$ emissions by their role in storing carbon, and their capacity to replace materials that result in high $CO_2$ emissions, would also substantially increase the sink capacity per unit area of commercial tree crops. To the extent that wood products replace fossil fuels used for energy production or replace high energy causing materials, the carbon displaced is a permanent contribution to $CO_2$ emission reduction. Tree crops could be "farmed" for carbon, and provided the wood products produced have relatively long lives the carbon sink formed over time would be greater than tree plantings that were grown to maturity without harvesting.

The current "Kyoto rules" applied inflexibility gives no recognition of the contribution of temporary sequestration. In addition to "buying time" temporary carbon sequestration does have an effect on potential global warming. For example, a re-released carbon dioxide molecule will have a smaller impact on global warming than when it was first sequestered because of the saturation effect with increasing $CO_2$ concentrations in the infra red spectrum. Each $CO_2$ molecule released in 2010 will have a 10 per cent less effect on global warming than it would have had if it was emitted in 1990 (Houghton *et al* 1994).

Bird (1997) derived a method of comparing reductions in $CO_2$ emission with carbon storage. He proposed that carbon-years be considered when evaluating the effect of carbon storage. He concluded, assuming a time horizon of 100 years, that storage of a tonne of carbon for one year was approximately equivalent to a permanent emission reduction of .0088 tonnes of carbon.

The most serious deficiency in the current carbon sequestration accounting "rules" is the absence of a mechanism to deal adequately with the "time dimension". All vegetation eventually dies and the carbon formed is returned to the atmosphere. It is possible to sustain a carbon sink forever by perpetual replanting. But this requires carbon sink sellers to accept a potentially large contingent liability.

## Measuring Carbon Sinks

Measurement of the amount of carbon sequestered by trees and other vegetation is technically relatively simple provided that the time horizon is specified. Total carbon biomass in vegetation and soil organic matter in vegetation types on different site types, at different stages of development, can be measured and compared to the original baseline or sink. The length of time that carbon is sequestered, and fluctuations in the size of the carbon sink caused by natural mortality or harvesting over a rotation, must also be considered to provide a realistic basis for offsetting $CO_2$ emissions against carbon sinks. There are a number of reports in the literature where perturbations in carbon sink levels over the rotation have been ignored resulting in significant over-estimates of carbon sequestration rates. Carbon storage times are often dealt with inadequately or ignored.

The "time dimension" and the effect of changes in carbon sink levels can be allowed for by determining the "average carbon sink biomass" over one or several rotations depending on the time horizon chosen (Greenhouse Challenge Sinks Workbook 1997). "Average standing carbon" is calculated by adjusting cumulative biomass curves (derived from stand growth functions) for mortality and harvesting and incorporating decay functions for residue (litter, dead roots, etc). The average sink is the sum of annual sinks divided by the rotation length, or several rotations, depending on the time horizon chosen. If timber products are excluded, the carbon sink that is formed on each hectare remains constant over time. Thus if vegetation is maintained in perpetuity, it is possible to determine a maximum permanent sink for any vegetation type. If timber products are included, decay functions for the timber products produced can be used to add their contribution to each year's standing carbon.

A carbon sink model has been used to predict changes in carbon sinks over time for several species currently being used for revegetation on farmland in Western Australia (Ritson pers. comm.). For example, Figure (1) shows the predicted carbon sink over three rotations of a typical maritime pine (*Pinus pinaster*) stand. The simulation assumes thinnings at ages 12, 18 and 24 years over a 30-year rotation and one year between clearfelling and replanting. Note that if the carbon contained in timber products is included, the average total sink continues to increase over successive rotations.

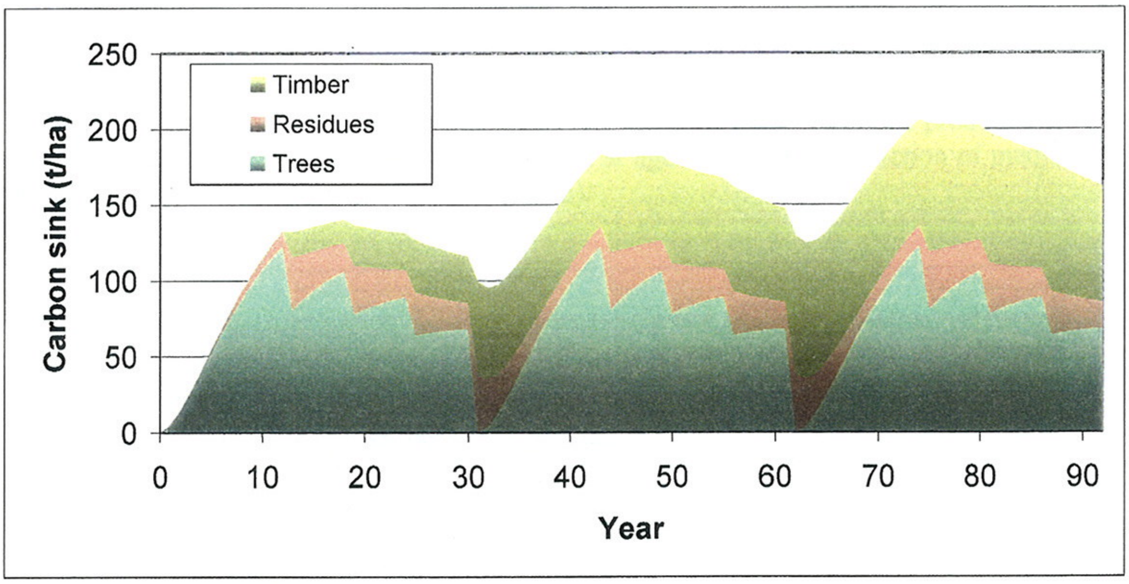


**Figure 1**
**Carbon sinks from Maritime Pine**

**Notes:**

1. Carbon sinks are: *Timber* – all harvest products; *Residues* – tree parts left after logging (stem tops, branches, bark, stump roots) and litter (fallen leaves and branches); and *Trees* --standing live biomass.
2. In the above decay rates of sinks defined by half-lives of 30 years for timber; 5 years for dead roots and stumps, and 3 years for other residues.

The annual and mean rate of carbon sequestration can also be determined from the standing biomass curve (Figure 2). Note that the rate of carbon sequestration reaches its maximum at a relatively early stage of stand development.

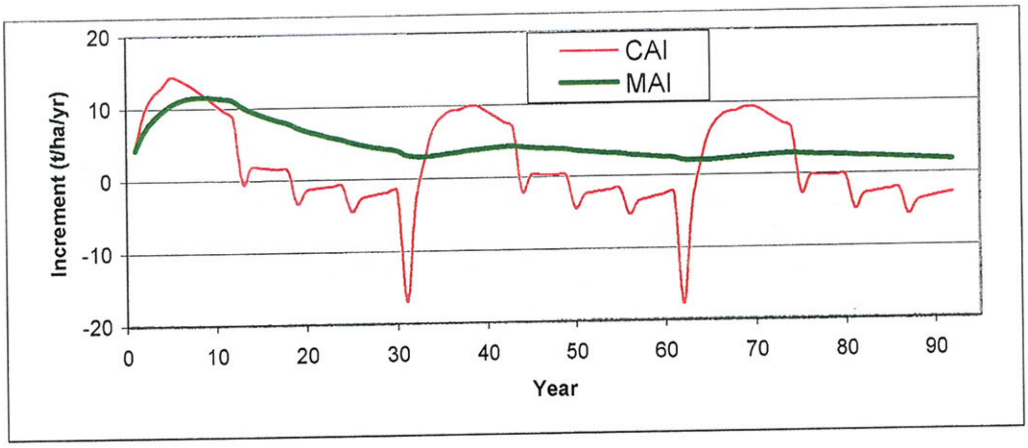


**Figure 2**
**Current annual increment (CAI) and mean annual increment (MAI) in predicted carbon sink over three rotations of Maritime Pine**

Changes in carbon sink levels and varying carbon storage times of carbon pools can be integrated by expressing carbon sequestration in "tonne years". It is possible to attribute a "carbon life" to each component of the annual increment of carbon that is produced by a stand of trees on a hectare each year by tracking it from formation until the end of the rotation, and for that proportion of the amount recovered that is converted into timber products, to the processing factory gate. This method makes it possible to compare the effect of different vegetation strategies involving different species, silviculture regimes and timber products on the quantity of carbon sequestered and the length of time it is removed from the atmosphere. Expressing carbon sequestration in units of tonne years may also provide a method by which emission reduction can be compared to carbon sinks (Bird 1997).

Operational data on the yield of timber from maritime pine logging operations, data on stand biomass and published data on timber products and residue decay times, were used in the model to estimate the number of "tonne years" produced on one hectare of maritime pine of average productivity, which is projected to be thinned three times and clearfelled at age 30, for the production of medium density fibreboard and laminated veneer lumber (Figure 3).

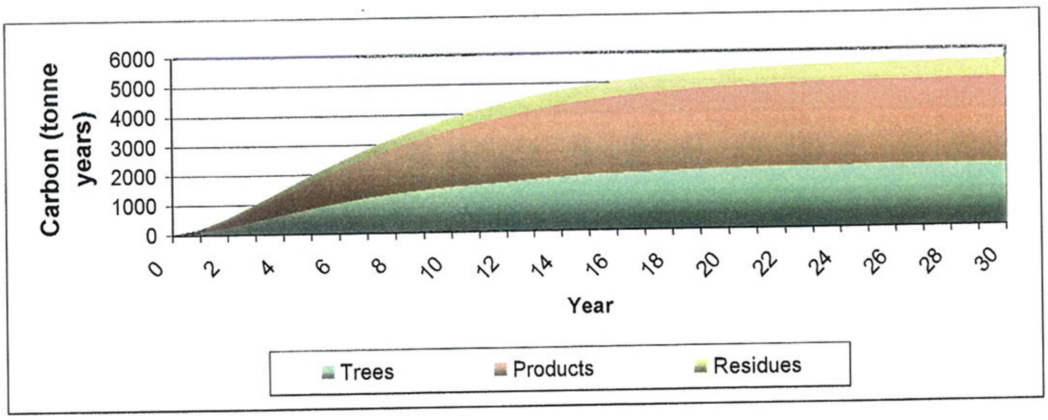


**Figure 3**
**Cumulative carbon storage for one hectare of Maritime Pine (tonne years)**

The relative contribution of different pools to the carbon sink formed by maritime pine has been calculated using the same assumptions as above (Figure 4).

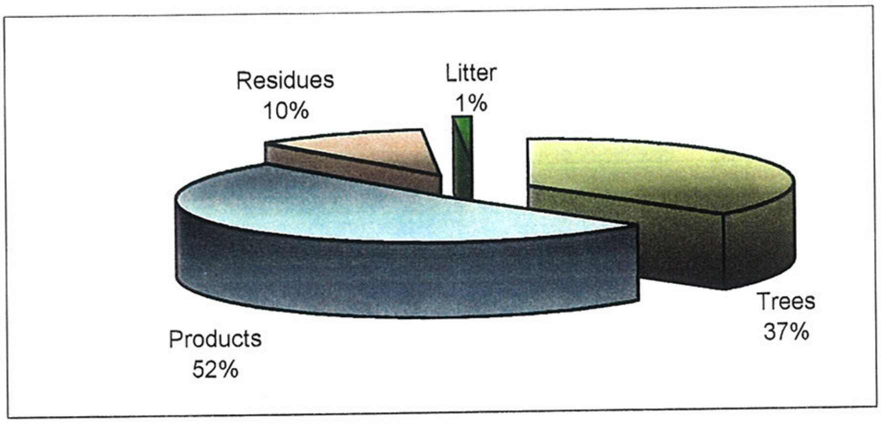


**Figure 4**
**Contribution of each pool to carbon storage (tonne years) of *P pinaster***

The carbon tonne years produced by one hectare of *E. globulus* grown over three 10-year rotations for the production of wood fibre for paper products illustrates the effect of rotation age and timber product type on the carbon sink (Figures 5 and 6). Even though *E. globulus* is more productive than maritime pine, its carbon sink is less because of its shorter rotation and the relatively low storage time of the wood products.

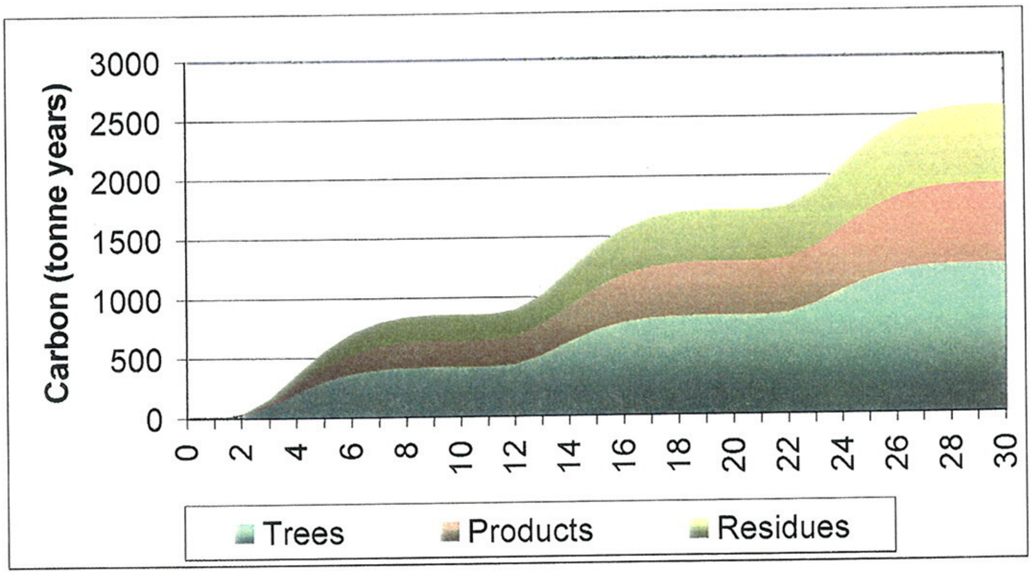


**Figure 5**
**Cumulative carbon sink for one hectare of**
***Eucalyptus globulus* (tonne years)**

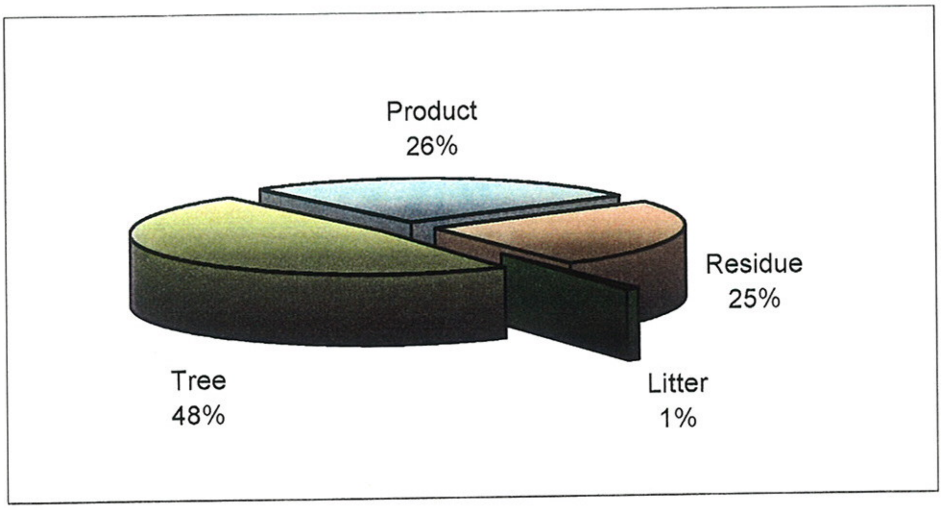


**Figure 6**
**Contribution of each pool to the sink (tonne years) of *E. globulus***

The size of carbon sinks formed by tree crops are significantly increased if credits are given for the "avoided emissions" that result from using wood fibre to replace products which generate high levels of greenhouse gases in their manufacture (Table 1).

**Table 1**
**Carbon Released and Stored and Fossil Fuel Energy used in the Manufacture of Building Materials**
**(Source F.W.P.R.D.C. 1997)**

| Material | Carbon released (kg/t) | Carbon released (kg/m$^3$) | Carbon stored (kg/m$^3$) | Fossil fuel energy (MJ/kg) | Fossil fuel energy (MJ/m$^3$) |
|---|---|---|---|---|---|
| Rough sawn timber | 30 | 15 | 250 | 1.5 | 750 |
| Steel | 700 | 5 320 | 0 | 3.5 | 266 000 |
| Concrete | 50 | 120 | 0 | 2 | 4 800 |
| Aluminium | 8 700 | 22 000 | 0 | 435 | 1 100 000 |

For example, Schopfhauser (1998) estimated for an average house more than half a tonne of carbon would be saved per tonne of extra wood used in construction.

The contribution of tree crops to reducing $CO_2$ emissions by replacing fossil fuels with bio fuels significantly increases the per unit area contribution of tree crops. New wood gassification technologies have made electricity production more cost effective and the use of biomass as a fuel becomes even more feasible when their use is integrated with the production of other wood products and when the below-ground component of the biomass is credited. For example, the carbon sink formed by mallee eucalypts would be more than doubled over a 50-year period if the above growth was used as a biomass fuel (Figure 7).

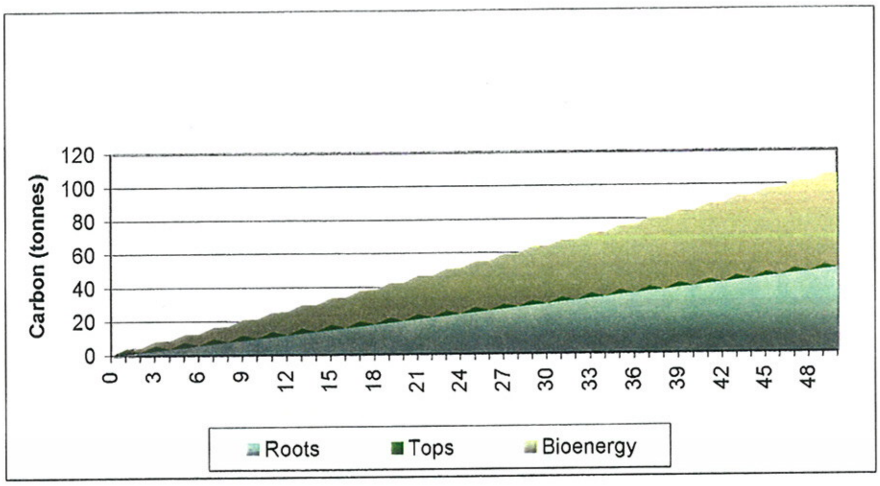


**Figure 7**
**Cumulative carbon sequestered from one hectare of mallee eucalypts when the above-ground biomass is used for fuel**

Preliminary estimates of the average standing carbon and the tonne years produced per hectare over a 30-year accounting cycle for each of the major species which are being used to revegetate farmlands in Western Australia (Table 2). These estimates include the carbon sinks formed by timber products for species which are currently used commercially, but they do not include $CO_2$ reduction which occurs when wood fibre is used to replace other materials which generate greenhouse gases.

**Table 2**
**Estimated carbon sequestered over a 30-year accounting period**

| Crop | Rotation length (yrs) | Carbon in various pools (tonnes/ha) | | | | Average carbon sink over 30 yrs (tonnes/ha) | Carbon storage (tonne years) |
|---|---|---|---|---|---|---|---|
| | | Tops | Roots | Litter | Products | | |
| Bluegum | 3 x 10 | 49 | 16 | - | 10 | 75 | 2598 |
| Maritime pine | 30 | 59 | 15 | 15 | 14 | 103 | 5600 |
| Oil mallee | 2 x 15 | 3 | 28 | - | - | 31 | 2510 |
| Landcare | Long term | 23 | 9 | - | - | 34 | 2804 |

Walker and Steffen (1992) suggest that the Australian rangeland soils can be used as a sink for carbon. They suggest that most carbon will be fixed in soil organic matter, with the move away from practices which cause land degradation. For example, they suggest that pastoral activity has decreased soil carbon content from 1.5 to 0.5 per cent across Australia's rangelands and that sequestration in the soil organic matter pool could be around 14 million tonnes.

There are no detailed data on the effect of destocking and fire management on total carbon accretion in the Western Australian pastoral zone, although major responses to destocking have been observed. It has been assumed that a living plant biomass increase above the degraded pastoral baseline of 10 tonnes per hectare (five tonnes carbon/ha) over a period of 30 years is achievable.

Quantifying carbon sinks is not technically difficult. But the absence of defined methods of measuring carbon sinks and, in particular, the absence of a defined time horizon has meant that published data on carbon sequestration rates and the cost of carbon sinks for various revegetation strategies in different parts of the world are difficult to compare. The effectiveness of a carbon sequestration strategy should be measured by the amount and length of time carbon is removed from the atmosphere. If this principle is accepted, it is logical to accredit the contribution of timber to carbon sinks formed from tree crops and the reduction in $CO_2$ emissions that result from the replacement of high greenhouse gas producing materials with wood fibre products.

## Monitoring and Verification

One of the reasons given for the reluctance of some signatories to the Kyoto Protocol to agree to include carbon sinks as part of national carbon accounting budgets is the concern that it will be impossible to accurately monitor and verify the amount of carbon sinks. Accurate and efficient monitoring systems, which can be audited, are also an essential prerequisite to the development of carbon trading systems. There are still uncertainties associated with measuring some components of carbon sinks (for example, soil carbon) and measurement of perennial shrubs. But procedures which have been developed to measure and audit commercial tree crops and commercial timber production and processing, which can be readily adapted to quantify carbon sinks, are already in place in most jurisdictions in Australia.

The components of a system for forecasting, monitoring and verifying carbon sequestration by tree crops based on existing procedures which is being developed in Western Australia by the Department of Conservation and Land Management (CALM) is illustrated in Figure 8 (page 9) and summarised below:

- ***Land Base***
  The potential area available for tree establishment is determined from site quality (site index) models and measurement of environmental attributes (climate, soils and landform). Aerial photographic and satellite imagery are used to stratify the target zone and estimate the potential plantable area.

- ***Stand Data***
  Growth prediction models, based on correlation of a number of climatic and site factors with stand growth in existing trial plots, are used to provide detailed site productivity maps for each stand. For example, prior to the establishment of *E. globulus* on farmland potential yields are estimated using an *E. globulus* Growth Simulation model (Figure 9). (Inions 1992).


**Figure 9**
***E. globulus* site productivity assessment for a typical farm. After (Shea *et al.* 1994)**

# Forecasting, Monitoring and Verification of Carbon Flows in Tree Crops from Establishment to Product Decay

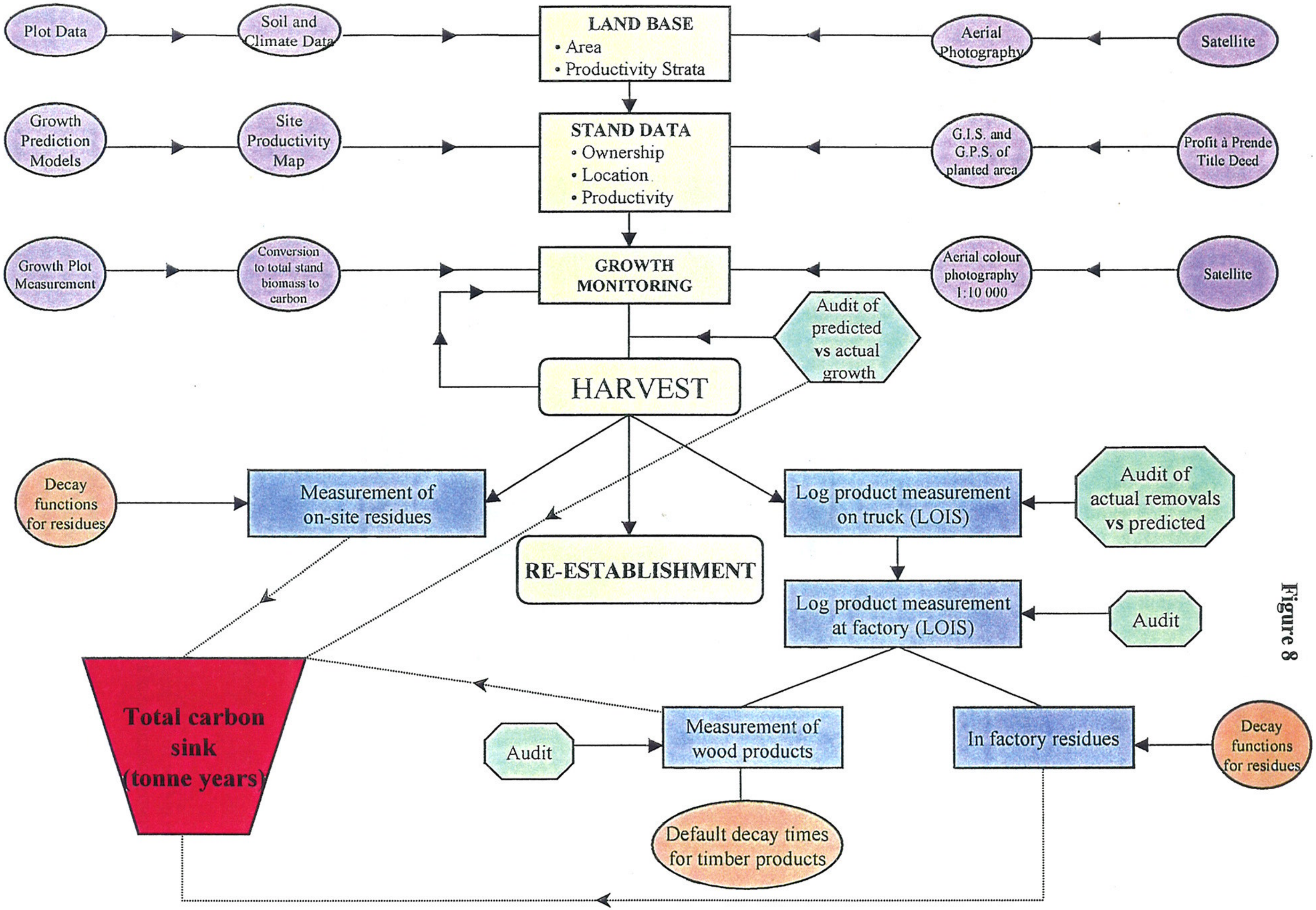


Figure 8

Once the stand is established, improved predictions of future growth are determined by incorporating stocking density and stand height to that age in the prediction models.

The location and area of the stand is delineated in the field using mobile geographic positioning systems and recorded in a geographic information system. The legal obligations of the landowner and tree crop investor, and the relative share of the products derived from the tree crop, are detailed in a legal contract based on the principle of profit à prendre. The contract is registered on the title deed.

- ***Growth Monitoring***

The crop area can be monitored and audited periodically using satellite imagery (Smith 1997) (Figure 10).

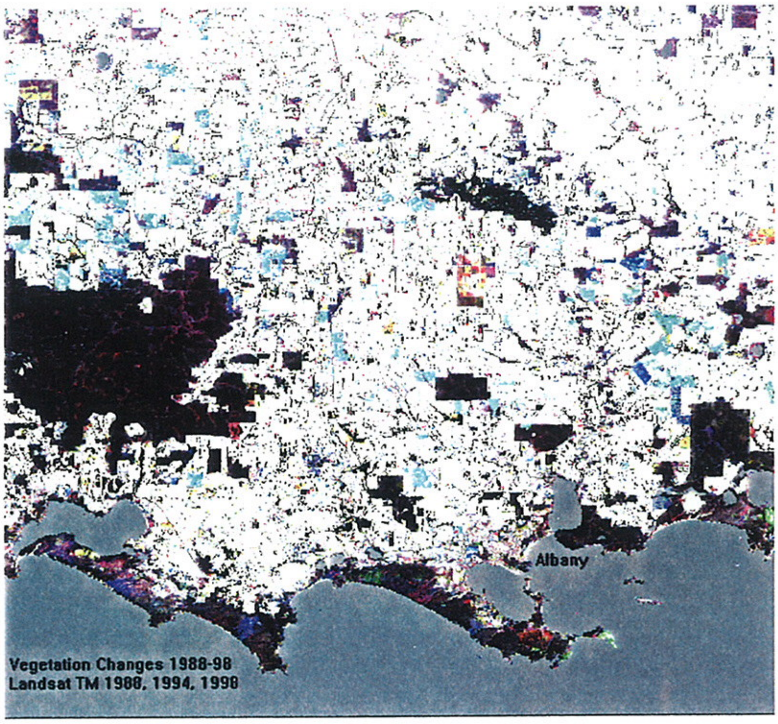


**Figure 10**
**Landsat image of Albany-Mt Barker region showing changes in vegetation from 1988-98. Scale 1:1,000,000**
**(Image provided by CSIRO Land Monitoring Unit)**

| | |
|---|---|
| Dark Blue | Vegetation recovery, new plantations 1988-94 |
| Light Blue | Vegetation recovery, new plantations 1994-98 |
| Yellow | Vegetation loss, clearing, fire 1988-94 |
| Red | Vegetation loss, clearing, fire 1994-98 |
| Green | Vegetation disturbance 1994, then recovery 1994-98 |

Stands are stratified using aerial colour photographs and growth plots are established within each stratum. Growth measures are taken throughout the rotation and compared to predicted growth.

For example, the 27,000 hectares of *Eucalyptus globulus* plantations established by CALM on privately owned farmland between 1987 and 1997 have been mapped in detail using aerial photographs and differential GPS ground surveys. Growth is monitored through the establishment of "early growth monitoring" plots, which both verify the establishment of planted trees and the rates of growth in early years. The plots are measured at 18 months and again three years; and the data are used to ensure that the correct growth curves are being used for prediction, and to identify the need for any remedial action if growth rates are not as predicted. A network of permanent growth plots are also maintained in all strata of the plantations through the rotation.

New technologies, including the use of large-scale video and laser altimetry has the potential to increase the capacity to increase the intensity and frequency of sampling at lower costs. (Tickle *et al* 1998).

The relationship between stem volume and total stand carbon varies with species, age and silvicultural treatment and can be determined by empirical measurements. For example, the ratio between bole volume and stand carbon has been established for *Pinus radiata* in New Zealand (Maclaren 1995). Intensive studies of the relationship between stand growth parameters and total stand carbon of several species at different stages of development on different site types are currently being undertaken in Western Australia.

- ***Harvesting***

  Strategies for the scheduling of actual log harvesting operations are simulated using a Pine and Hardwood Scheduling System. These systems have an ORACLE application, with each uniform stand represented individually in database tables describing stand details, yield regimes (including next rotation if relevant), haulage distances and product destinations. Any of these variables may be varied to examine their effect on wood supply options. The system is used to generate both long-term (strategic) plans and short-term logging or fertilising plans. Unique stand identifiers link the database information to GIS spatial records. Each of these systems can be adapted to predict the impact of any management activity on the current and future status of the carbon sink in all stands.

  All log removals (including log product categories) during harvest from each compartment are recorded using CALM's Logging Operation Information System (LOIS) and are subject to internal and external audit at any stage of transport from the field to the factory door. The information is retained on computer and consequently it is possible to efficiently and rapidly compare actual timber removals from each stand with predicted yields.

  The proportion of the total biomass left after harvesting can be determined by subtracting the bole volume utilised from total biomass. Currently, "default" decay functions have been used to estimate the carbon life of the residue. But it is proposed to determine actual decay rates by field measurements.

- ***Processing***

  The Logging Operation Information System (LOIS) requires measurement of all logs and their separation into different log categories which correspond to different timber products at the factory using weighbridge or log scanning systems and is subject to internal and external audit. It is normal practice for factory or sawmill managers to maintain detailed records of recovery rates for different products and the residue produced for commercial reasons. Most mills and factories processing logs purchased from CALM have, as a condition in their log supply contract, an obligation to provide data on product recovery rates from different log categories. Thus it is possible to determine the amount of carbon that is harvested from the stand in each timber product produced.

- ***Timber Product Decay Functions***

  The decay rates of timber products have been the subject of a number of studies (Hollinger *et al* 1993, Arima 1993, Cannel *et al* 1995, Maclaren 1996, Karjalainen 1996). Further research is required but it is not unrealistic to assume that it will be possible to determine decay functions for various timber products that are acceptable to the international authorities who are responsible for the promulgation of "greenhouse" accounting rules.

The existing system that has been developed to measure, monitor and audit tree growth and timber products in Western Australia with relatively minor modifications can be used to quantify carbon sinks and carbon storage times. Stringent internal and external auditing procedures are already applied for commercial reasons and they could readily be elaborated to meet international carbon auditing requirements.

## Critical Elements of Carbon Sequestration Strategies

### Land availability

There are large areas of land in many countries that have the potential to establish trees or other types of perennial vegetation to create carbon sinks. However, the availability of suitable land is a major constraint on the establishment of tree plantations or crops for carbon sequestration because of political, social and economic constraints. For example, land ownership is often complex and not amenable to the application of commercial legal principles and thus the long-term legal security of the land is not assured. Even if there are no legal barriers to purchasing land, large-scale land purchase requires a major capital investment and it is often unpopular with local communities.

Western Australia has a large land-base that is potentially available for carbon sequestration. Western Australia's south-west agricultural area extends over 18 million hectares (Figure 11) (Table 3). The winter-dominant annual rainfall ranges from 1300 mm in the south-west corner to the inland wheatbelt/pastoral zone boundary roughly along the 250 mm rainfall isohyet.

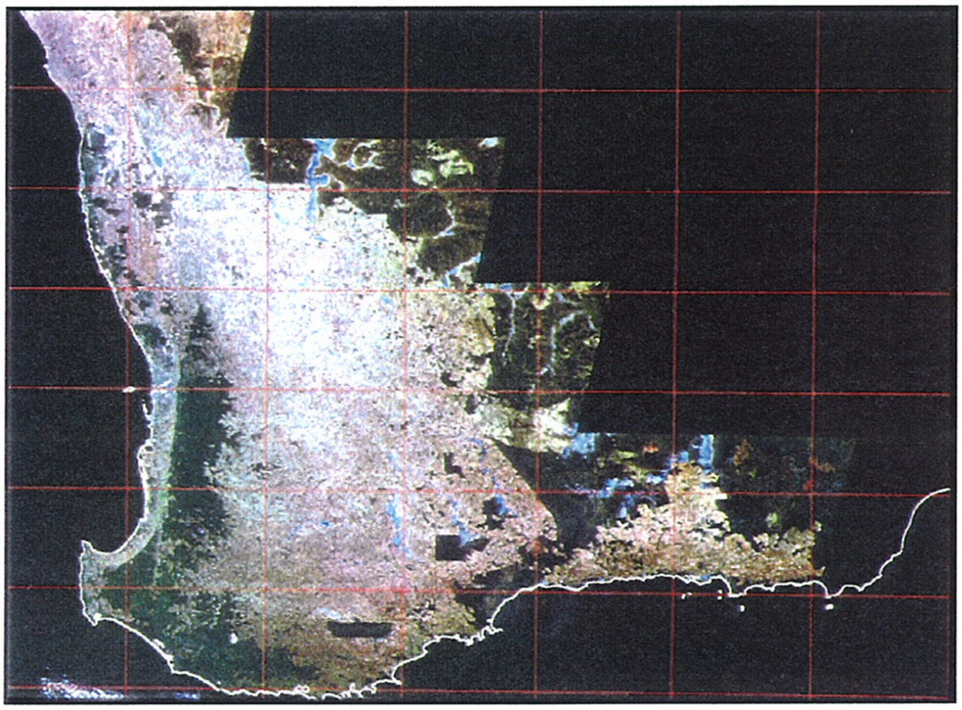

**Figure 11**
**Landsat mosaic of south Western Australia. Scale 1:10,000,000.**
**(Image supplied by DOLA© ACRESA AUSL16)**

**Table 3**
**Landuse in the south-west of Western Australia (Beetson *et al* 1994)**

| Land Use | Area (million ha) | % of area within the agricultural region |
|---|---|---|
| Agricultural region (>250mm rainfall) | 25.25 | 100.0 |
| Private land | 20.73 | 82.0 |
| Private land under agriculture | 17.98 | 71.2 |
| Private with original native vegetation | 2.75 | 10.9 |
| Public land (State forest, reserves, parks) | 4.52 | 17.9 |

It is estimated that 3 million hectares of private agriculture land would be available for the establishment of commercial tree crops or non-commercial "landcare" species on cleared privately-owned land.

The sheep grazing pastoral (rangelands) region of the southern half of Western Australia extends over 85 million hectares. It is estimated that 10 per cent of the region (8.5 million hectares) could be available for rehabilitation – principally by destocking and managing fire.

In the 1980s the Department of CALM developed a system to integrate commercial tree crops into agricultural systems in Western Australia primarily in response to the need for the establishment of perennial crops on farmland to reverse land degradation (Shea and Bartle 1988, Shea *et al* 1994, Shea 1998). Farmers and local authorities recognised the benefits of tree planting but were concerned about the social and economic impact of whole farm purchase for afforestation. Consequently, a legal contract was developed that allowed tree crops to be planted on farmlands to achieve multiple objectives without affecting farm ownership and also providing long-term security of the tree crop.

The contract, based on a profit à prendre, allows the landowner to sharefarm with an investor. Under the sharefarming scheme developed by CALM, the landowner retains ownership of the land and allows an agreed area to be used to grow a commercial tree crop, which is paid for by the investor and managed under contract with the investor by CALM. The contract is registered on the title deed and consequently is automatically transferred if the property is sold. The revenue from the trees is shared between the landowner and the investor.

Profit à prendre is superior to a lease, because in one simple document it enables the landowner to share the profits from the use to which the land is put, but also to continue using it himself (if the use does not conflict with the agreement). Sharefarming under profit à prendre greatly assists integration of trees into the farm. It provides practical flexibility, accentuating economic returns to the farmer and the investor, providing security for both and maximising the environmental benefits of tree planting. CALM has established more than 1,000 sharefarm agreements with farmers to establish tree crops on privately-owned land since 1987.

The original legal document which was designed to share the returns from timber production between the landowner and the investor according to their contribution to growing the tree crop has been modified to incorporate a potential new product from tree crops - carbon. The contract provides for the landowner to obtain the rights to a proportion of the carbon sink that is created in proportion to his input into the tree crop (the value of the land). The proportion varies according to land values but is in the range of 15-35 per cent. The landowner has the option of selling his rights to the investor.

## Security

The creation of carbon sinks is a long-term business and thus must be carried out in an environment which is stable politically and physically safe. Western Australia has been establishing tree plantations for 100 years and there have been no significant losses from the plantation estate from fire or disease.

## Integration with Environmental and Economic Objectives

Carbon sequestration strategies that are designed so that they complement other environmental and economic objectives will result in lower costs and have greater social acceptability and political security.

Nature conservation, water quality, agriculture and rural infrastructure are all at risk from salinity in Western Australia's south-west agricultural region. The amount of land already damaged by salinity totals 1.8 million hectares, or nine per cent of the region. The Western Australian Salinity Action Plan (1996) estimates that total damaged land will exceed six million hectares (32 per cent) within several decades unless urgent remedial action is taken.

This threat is posed in a region that is internationally acclaimed for its diversity of native vegetation. The south-west land division has an estimated 9,000 plant species of which more than 70 per cent are endemic. The biodiversity of the region has already been compromised by the scale of land clearing for agriculture – for example, 43 species in the agricultural region have become extinct (Armstrong and Abbott, 1995).

The Salinity Action Plan focused on revegetation as the major solution, to modify the agricultural water-use pattern back towards that which prevailed under virgin forest and woodland. The plan projected the need for an extra three million hectares of woody perennial plant cover to achieve salinity control. The cost of this will exceed $3 billion.

It is unlikely that this level of funding will be achieved unless a proportion of the revegetation required can generate a commercial return. The commercial return from some tree crops in some areas of the State are sufficient incentive for private investment. But in large areas of the agriculture zone it is either not possible to grow commercial tree crops or the returns from commercial tree crops are marginal. The additional returns from carbon sinks credited by perennial vegetation have the potential to pay for landcare planting, improve the internal rate of return on commercial tree crops to levels capable of attracting private funds, and help develop new tree crops and industries. (Shea 1998).

The cost of carbon sequestration can be reduced significantly if there is a market for the wood fibre produced. Western Australia's forest industry sector utilises all of the resource produced from existing plantations and there are a number of proposals to expand existing manufacturing facilities and establish new ones when resource becomes available. CALM currently manages 72,000 hectares of State-owned pine plantations and 27,000 hectares of bluegum plantations, most of which are privately-owned. CALM's plantation estate has timber products with a current estimated worth of at least $230 million. A total of 600,000 cubic metres of logs is supplied annually from these plantations to locally-based private forest products manufacturing companies producing sawn timber panel products, and a variety of other wood products.

The injection of funds into regional Western Australia from carbon sequestration projects, particularly when they are linked to commercial tree crops, would also make a significant contribution to regional employment. For example, a study commissioned by Albany Port Authority estimated that in 1997, 216 people were employed directly and indirectly on bluegum plantations established over the previous 10 years in the Great Southern region and that these plantations provided $46 million directly and indirectly in wages and other income.

## Availability of Suitable Species

There are several species which have been exclusively researched and trialed throughout the south-west of the State or which grow naturally in the proposed planting zone.

- *Maritime Pine* (*Pinus pinaster*)
  This species has been grown in Western Australia for more than 80 years principally on sandy soils on the coastal plain. The species has been established on a smaller scale throughout the 400-600 mm rainfall zone within the agricultural region and extensive plantings have commenced in this region as part of the State's salinity strategy. The average yield is expected to be 360 cubic metres of commercial timber generating an average carbon sink of 103 tonnes per hectare over a 30-year period.

  The rotation for maritime pine is 30 years with thinnings at age 12, 18 and 24 years producing material for a variety of wood products, including medium density fibreboard (MDF), panel-board products and sawn timber.

  The maritime pine planting program is underpinned by an extensive research program which has been undertaken over several decades. For example, a tree breeding program initiated 50 years ago will produce maritime pine 140 per cent more productive than the original unimproved trees imported to Western Australia from Portugal in the 1940s.

- *Tasmanian Bluegum* (*Eucalyptus globulus*)
  Over 100,000 hectares of Tasmanian bluegum have been established on farmland by private companies and the Department of CALM in the >600 mm rainfall zone over the past 10 years in Western Australia (Figure 12).

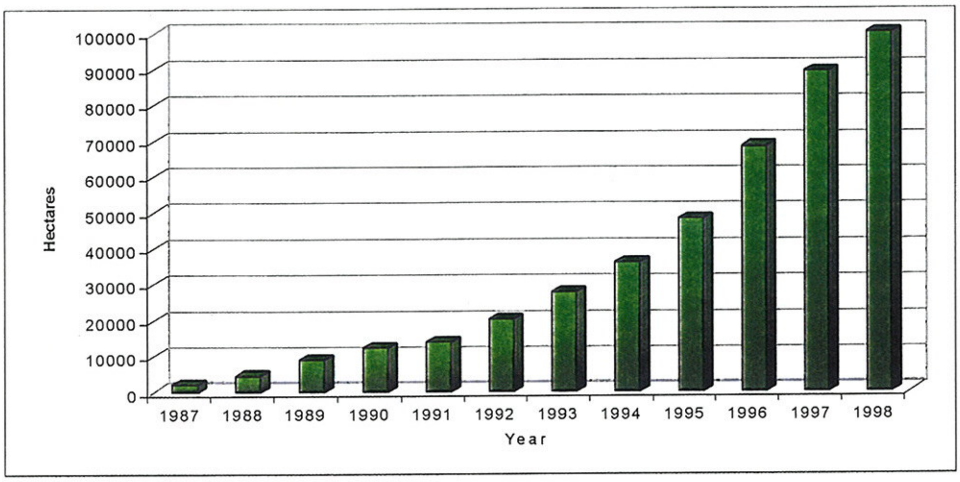


**Figure 12**
***Eucalyptus globulus* tree crops established since 1987**

Tasmanian bluegum is grown on a 10-year rotation with regeneration from coppice for two successive rotations. One hectare of Tasmanian bluegums produces an average 250 cubic metres of wood fibre and an average carbon sink of 75 tonnes/hectare over a 30-year period. Currently, the major end-product is wood fibre for paper pulp but the wood from this species can be used for a variety of timber products.

- *Mallee Eucalypts*

  Mallee eucalypts form a large lignotuber and root system and multiple stems which resprout vigorously after fire or harvest. Many mallee species were present in the original native vegetation of the wheatbelt but are now confined to remnants. Several mallee species with high leaf oil content have potential as short rotation tree crops producing eucalyptus oil. The oil has traditional uses, especially in non-prescription pharmaceuticals, but this market is small. However, eucalyptus oil has been shown to be an excellent natural solvent that could be developed for large-scale industrial use (Barton and Knight 1997). Seven thousand hectares of mallee eucalypts have been planted on private farmlands with a view to future commercial harvest for eucalyptus oil, but mallees are also an excellent general farm tree contributing to landcare and biodiversity.

  Oil mallee is grown in twin row hedges with two metres between rows – one kilometre of hedge is equal to one hectare. Preliminary data on growth and biomass production have been collected from representative sites in the 300 to 350 mm rainfall zone (McCarthy pers. comm.). The typical proposed rotation is to harvest at age four, then harvest coppice crops taken on a two-year cycle. Based on preliminary measurements at age four the above-ground carbon mass will average six tonnes/ha and below-ground two tonnes/ha. Each subsequent biennial coppice harvest yields the same as the first harvest. Hence the average standing above-ground carbon is maintained at three tonnes/ha. Roots initially grow at one tonne carbon/ha/year but growth rate decelerates to a plateau over a period in excess of 100 years. Initial data from mature mallee retained in belts in farmland indicate very large root biomass (up to 200 tonnes biomass or 100 tonnes C/ha at maturity). The above-ground component of the biomass could potentially be used as a fuel. Over a 30-year period assuming 14 harvests, 84 tonnes of above-ground carbon, including 42 tonnes of carbon as wood suitable for use as fuel and 28 tonnes of roots are produced.

- *Landcare*

  Landcare plantings are very diverse in species composition, planting density, management input and quality of land. They are frequently planted on poorer sites to avoid good cropping land, for example adjacent to salt-affected land or on eroded soils. This reduces their growth (and carbon sink) potential. However, unlike commercial tree crops, landcare trees are not harvested and therefore build up a standing biomass that is retained for long time-periods. Landcare trees are also commonly protected from grazing and may develop larger litter and soil carbon pools. They have a sigmoidal growth curve with sink size plateauing out at age 30 to 50 years. There are no detailed local growth data available for landcare plantings. Growth rates of 2.5 $m^3$/ha/year have been assumed.

  The potential land area available for planting each of these species is shown in Table (6).

## Infrastructure

Major revegetation projects, if they are to be successful, require a significant physical and skills infrastructure. In Western Australia there is an existing infrastructure which can rapidly be expanded. For example, in addition to its own staff, CALM employs 80 private contractors located throughout the planting region to implement the existing tree planting program. There are several private companies carrying out large tree planting programs. A major tree seedling nursery, located at Manjimup, has the capacity to produce 25 million seedlings and is currently being expanded to allow production of 60 million seedlings per annum. Genetically improved seed is available from seed orchards for eucalyptus species and the nursery has the capacity to produce cuttings from genetically improved maritime pine.

## Costs

The costs per tonne of sequestering carbon is a function of a number of factors. The ability to offset sequestration costs against other commercial products that are produced, however, has a major effect. The estimated cost of sequestering a tonne of carbon in Western Australia using current operation costs and current prices for timber products assuming a 30-year accounting cycle is shown in Table (4).

**Table (4)**
**Estimated costs per hectare of establishment and management and estimated costs of carbon sequestration based on a 30-year accounting cycle without replanting for different species**

| | Bluegum | Maritime pine | Oil mallee | Landcare |
|---|---|---|---|---|
| Average stand carbon | 65 | 89 | 31 | 34 |
| Average total carbon | * 75 | * 103 | 31 | 34 |
| Total cost | $11,598 | $2,340 | $1,300 | $1,700 |
| Total revenue | $18,750 | $6,518 | Not yet commercial | $0 |
| PV** of costs | $ 5,228 | $1,701 | $1,051 | $1,424 |
| PV of revenue | $ 5,246 | $1,262 | Not yet commercial | $0 |
| PVC/tonne of net carbon | $ 69.70 | $20.65 | $42.36 | $52.37 |
| PVR/tonne of net carbon | $ 69.95 | $15.32 | Not yet commercial | $0 |
| Net PV (cost) tonne of net carbon | -$ 0.25 | $ 5.33 | $42.36 | $52.37 |

* Includes carbon sinks in timber products
** Discount rate 7%

It is possible to calculate the costs of maintaining the carbon in a permanent sink, although prediction of management costs and revenues from timber products produced beyond 30 years is problematical. For example, the additional discounted cost incurred per tonne of carbon by replanting maritime pine after the first rotation is $1.68.

The internal rate of return from carbon sequestration projects using different species has been calculated assuming carbon which is priced at 0, $20 and $40 a tonne and current log prices Table (5).

**Table 5**
**Estimates of yields, costs and commercial returns over a 30-year accounting cycle for different species**

| Species | Net discounted cost per tonne of carbon sequestered | Carbon @ $0/tonne | Carbon @ $20/tonne | Carbon @ $40/tonne |
|---|---|---|---|---|
| Maritime pine | $5.33 | 5.4% | 11.3% | 21.1% |
| Bluegum | -$0.25 | 7.0% | 10.8% | 15.6% |
| Mallee eucalypt | $42.36 | | -8.3% | -2.0% |
| Landcare species | $52.37 | | -8.8% | -3.2% |

## Measurement and verification

It is essential that carbon sinks can be measured and audited efficiently. It is not anticipated that the cost of modifying the existing system that has been developed to measure and audit stand growth and timber production will significantly increase existing costs.

## Implementation rate and scale

Carbon sequestration by the establishment of trees and/or rehabilitation of natural vegetation will have to occur on a large scale and be initiated within the next 2-5 years if it is to make a significant contribution to offsetting emissions in the first commitment period. Tree growth, even on productive sites, follows a sigmoidal curve and takes several years before maximum growth rates are achieved.

The existence of an accessible land-base, legal system, infrastructure and technology that has been developed for the tree crops program on farmland in Western Australia provides the opportunity to rapidly implement a large-scale carbon sequestration program. It is estimated that it would be possible to sustain a carbon sink of approximately 200 million tonnes assuming a 30-year accounting cycle (Table 6).

**Table 6**
**Land availability and estimated total carbon sequestered over a 30-year accounting period**

| Rainfall zone | Treecrop zone (mm) | Gross area (million ha) | Potential for revegetation | Projected planting area (ha) | Average carbon sequestered (tonnes/ha) | Total carbon tonnes sequestered over 30 years |
|---|---|---|---|---|---|---|
| | Maritime pine | | 30% | 100 000 | * 103 | 10 300 000 |
| >600 | Bluegum | 2 | | 250 000 | 75 | 18 750 000 |
| | Landcare species | | | 250 000 | 54 | 13 500 000 |
| 400-600 | Maritime pine | 6 | 25% | 500 000 | * 103 | 51 500 000 |
| | Landcare species | | | 1 000 000 | 40 | 40 000 000 |
| 250-400 | Mallee eucalypts | 10 | 10% | 500 000 | 31 | 15 500 000 |
| | Landcare species | | | 500 000 | 27 | 13 500 000 |
| <250 | Pastoral regeneration | 85 | 10% | 8 500 000 | 5 | 42 500 000 |

* Assumes credit for carbon contained in timber products

If the planting program could be implemented over a 10-year period – a challenging but achievable task – it is estimated that the average annual $CO_2$ emission offset for the first commitment period would be approximately 9.3 million tonnes of carbon or 34 million tonnes of $CO_2$ (Figure 13).

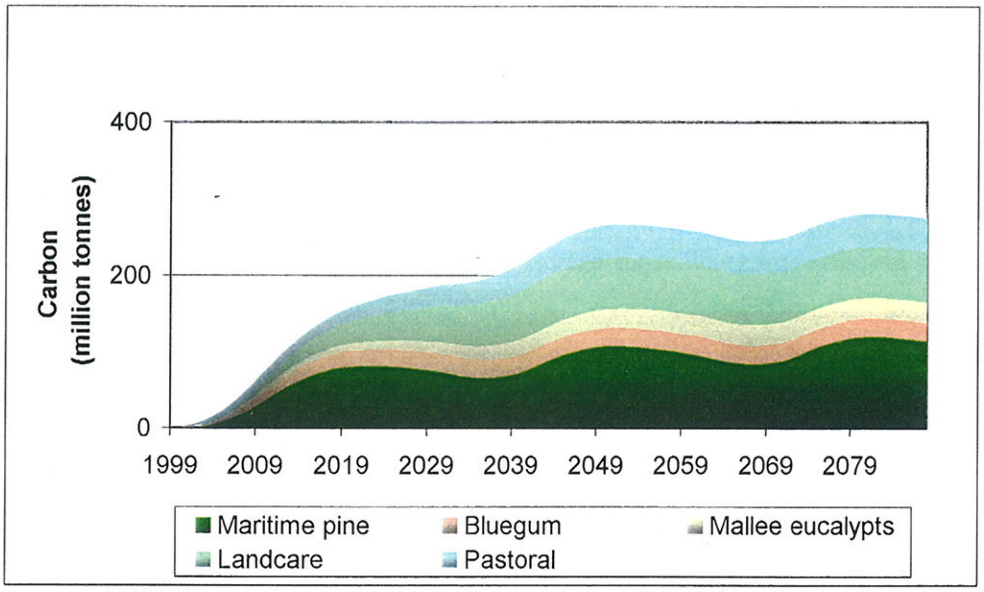


**Figure 13**
**Cumulative carbon pool over 90 years (assuming a 10-year establishment program)**

## Conclusion

There is considerable uncertainty surrounding the rules that will govern the accreditation of carbon sinks. But the Protocol does allow accreditation of carbon sinks, and for the first commitment period carbon sinks are equivalent to emission reductions.

The Kyoto Protocol, if ratified, will require Australia to meet its emissions target by the first commitment period which is less than ten years away. Carbon sequestration can only be one of a number of measures that must be implemented if the increase in carbon dioxide emissions are to be reduced. But carbon sequestration can make a significant contribution and provide time to develop and implement other methods of reducing emissions.

If carbon sequestration, however, is to be used to meet the Kyoto commitments by the first assessment period in 2008-2012, it will be necessary to commence large-scale planting programs within the next 2-6 years. If no action is taken before the uncertainty surrounding carbon trading and carbon accounting as it applies to sinks is resolved, the trees will not have reached significant carbon sequestration rates by the first commitment period.

The uncertainty about carbon accounting rules and carbon trading can best be reconciled with the need for rapid implementation of a revegetation program by designing carbon sequestration projects which minimise risks and costs by integrating them with other landuse and economic strategies. Western Australia has the capacity to develop large carbon sinks, which can be monitored and verified, over a relatively short period of time. The costs of sequestration can be minimised by incorporating commercial tree crops and the political and social acceptance of the programs would be enhanced by the major contribution that large-scale revegetation of cleared agricultural land would make to reducing land degradation and restoring biodiversity in Western Australia.

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