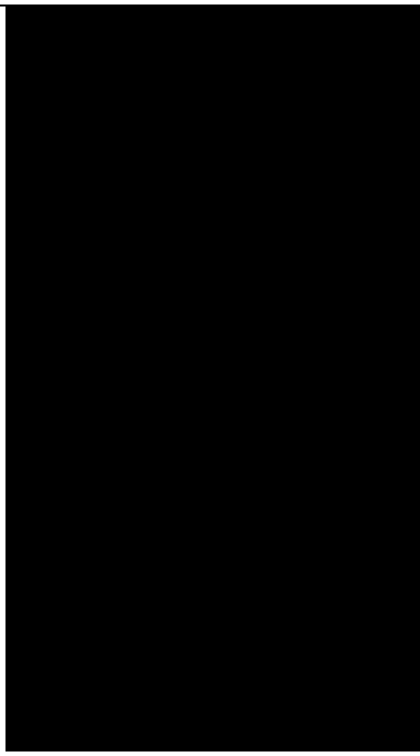
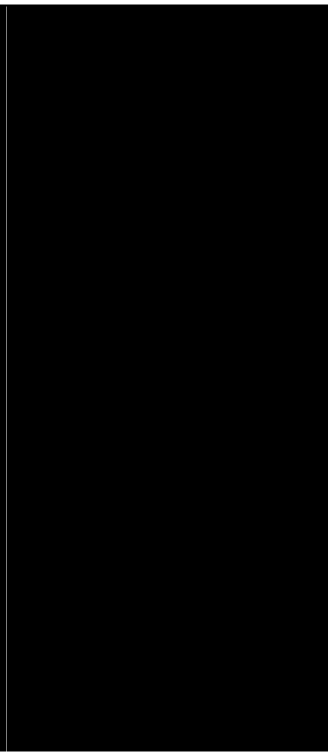
# Identification of Plantation Expansion Opportunities in New South Wales - Eden CRA Region

A report undertaken for the NSW CRA/RFA Steering Committee

April 1998





# Identification of Plantation Expansion Opportunities in New South Wales - Eden CRA Region

BUREAU OF RESOURCE SCIENCES,
in conjunction with
STATE FOREST NEW SOUTH WALES
and
AUSTRALIAN BUREAU OF AGRICULTURAL AND RESOURCE ECONOMICS

**A report undertaken for the NSW CRA/RFA Steering Committee**

**project number NA 07/ES**

**April 1998**

Report Status

This report has been prepared as a working paper for the NSW CRA/RFA Steering Committee under the direction of the Economic and Social Technical Committee. It is recognised that it may contain errors that require correction but it is released to be consistent with the principle that information related to the comprehensive regional assessment process in New South Wales will be made publicly available.

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This project has been jointly funded by the New South Wales and Commonwealth Governments. The work undertaken within this project has been managed by the joint NSW / Commonwealth CRA/RFA Steering Committee which includes representatives from the NSW and Commonwealth Governments and stakeholder groups.

The project has been overseen and the methodology has been developed through the Economic and Social Technical Committee which includes representatives from the NSW and Commonwealth Governments and stakeholder groups.

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# EXECUTIVE SUMMARY

As part of the Comprehensive Regional Assessment (CRA) process, a study was conducted to identify areas potentially suitable for plantation development in the Eden Regional Forest Agreement (RFA) region. The study, consisting of three parts: capability, suitability and economic analysis, was confined to cleared private land. Potential was gauged in respect of two species, a softwood species, radiata pine (*Pinus radiata*) and a native hardwood, shining gum (*Eucalyptus nitens*).

This study examined existing literature and found that previous studies had their limitations, the important ones being: lack of comprehensive economic analysis, use of very coarse data, not covering the specific RFA region, being qualitative (descriptive) rather than quantitative, or not providing maps to show the location of potentially suitable land and its productivity ranking.

The study also looked at the existing resource which cover 35 500 hectares being predominantly *Pinus radiata.* The current (1997) harvest from this resource is 50 000 cubic meters of sawlog and 35 000 tonnes of pulpwood per year. The resource is currently under utilised due to lack of markets, especially for pulpwood. The estimated potential harvest (given adequate markets) by 2002 is a six fold increase in sawlog production and an eight fold increase in pulpwood production, rising to an eleven fold increase by 2020 from current levels.

The physical capability of sites to grow plantations was evaluated by using GIS and statistical techniques. A mathematical relationship between a site productivity measure (site index) and environmental variables (climate, soils and terrain) was developed for existing plantations. For the rest of the analysis area, site productivity was extrapolated from this relationship. Current land uses were mapped using both satellite data and local government environmental plans. These land-use categories range from various grazing categories to dairying land-use. The capability and suitability aspects of the study were conducted in parallel. The former assessed the physical capacity of sites to grow the recommended species while the latter assessed the suitability of the land in terms of its current land use and planning regulations.

A total of 198 000 hectares out of 236 000 hectares of cleared private land were identified as suitable for *P. radiata* plantations. Of that land, about 88 per cent was rated of medium productivity potential or higher and the remainder was rated low productivity potential. In respect of *E. nitens* plantations, approximately 67 000 hectares were identified as suitable, however, only about 9 per cent was rated medium productivity potential or higher. Most of the suitable land (98%) was found to occur on relatively flat land, with a slope less than 18$^{o}$.

The economic analysis compared the estimated existing agricultural land values with the estimated values of plantation development. Three product price scenarios (baseline, -10 per cent, + 10 per cent) and three productivity scenarios (baseline, lower and upper 95 per cent confidence limits) were considered for each management regime. Two management regimes, sawlog and pulplog, were considered for *P. radiata* and a pulplog regime was considered for *E. nitens*. Only a pulplog regime was considered for *E. nitens*

because sawlog yield and market price were unavailable.

The estimated net present values from plantation development were found to be sensitive to product prices. Under the different price scenarios, the area of land where the land value from plantation development was greater than the estimated existing agricultural land values ranges from 82 000 hectares (low price scenario) to 197 000 hectares (high price scenario).

For 66 per cent of the land, the radiata sawlog regime generates the highest plantation values under the baseline price scenario. The pulplog regime generates the highest plantation values on 88 per cent of the area under the high price scenario.

The *Eucalyptus nitens* regime does not generate the highest plantation values for a significant amount of land under any scenario. Whilst it was not the preferred species it nevertheless generates higher net present values than existing land uses on approximately 4600 hectares in the baseline scenario. This was very sensitive to price with the low price scenario showing only 400 hectares with a higher net present value than existing agriculture and approximately 14 000 hectares in the high price scenario.

The area of land where plantation net present values are greater than existing land uses does not vary greatly between the upper and lower 95 per cent confidence limits of the baseline site index area, 154 000 versus 165 000 hectares respectively.

An estimate of wood flows was made assuming 10 per cent of the land area found suitable was converted to the highest value plantation development. This showed wood flows ranging from 136 000 $m^3$ (low price scenario) to 338 000 $m^3$ (high price scenario) per year. Looking at a hardwood option alone and assuming 10 per cent of the areas suitable were converted to *Eucalyptus nitens* would result in wood flows ranging from 1250 $m^3$ (low price scenario), 7400 $m^3$ (baseline) to 17 300 $m^3$ (high price scenario) per year.

Overall, this study found that there are significant areas in the Eden CRA/RFA region where the potential net present values under plantation is greater than existing estimated net present values. However, for the plantation potential to be realised, a significant level of investment in the timber processing industry will also need to occur. Apart from economic returns, other factors such as planning regulations and perceived environmental advantages/disadvantages will undoubtedly influence many plantation development decisions.

# 1. INTRODUCTION

## 1.1 PURPOSE

A consideration of the Comprehensive Regional Assessment (CRA)/Regional Forest Agreement (RFA) process is an assessment of plantation potential to identify the options for meeting the demand for certain types of timber products. Additionally, there is an agreed national goal to treble Australia's plantation estate by 2020 through a strategy called the Plantations 2020 Vision (Plantation 2020 vision implementation committee 1997). At a State level, the New South Wales State Government aims to establish 10 000 ha of hardwood plantations in 1997-98 and to eventually double the existing area (200 000 ha) of softwood pine plantations.

The combined purpose of this plantation potential study was to investigate the feasibility of expanding the plantation estate, identify the land area in the Eden study area that is capable of meeting the government's objectives and give an estimate of the suitability of this land for plantation purposes.

## 1.2 OBJECTIVES

To meet the purpose described above, objectives were developed within this project framework. These were to review, consolidate, develop and extend existing studies into land suitability and wood flow projections for plantation development options, having regard to:

- physical land capability (topographic and edaphic);
- climatic suitability;
- potential productivity;
- economic potential;
- environmental sensitivity;
- scale and proximity to existing and potential markets; and

In order to identify total potential woodflows from plantations, the volumes from existing plantations have also been included in this report.

Information on the areas potentially suitable for plantation establishment is important in the CRA process and is one of the key inputs into the economic and social assessments.

The project provides maps and tabular information describing the potential for establishment of key plantation species across the landscape. The plantation potential of an area can be characterised by its capability to grow target species, and its suitability in terms of land value, infrastructure and other economic factors.

The basic concept underlying capability modeling is that vegetation has a potential growth and yield that is determined by the site and the vegetation type. The site includes climatic, edaphic (soil) and radiation factors. Vegetation types exhibit different growth rates depending on the species and the age mixes.

Plantation suitability modeling looks at the more realistic aspects of whether sites identified as being capable of growing plantations are suitable from an economic, environmental (slope), and opportunity cost viewpoint. Legal impediments, such as planning scheme controls and environment protection legislation are addressed as well as site specificity issues in Chapter 6.

## 1.3 SCOPE

The Eden Study Area (i.e., the area assessed by this project) covers the Eden CRA region and extends to a line running north from the most western point of the CRA region and a line running east/west from the most north point of the region. This enabled inclusion of the Bombala State Forests of NSW (SFNSW) Softwood Management Area. It was essential to include the Bombala Management Area as it is a significant plantation estate and there is a high probability of identifying suitable land around this existing estate. A map of the Eden Study Area is shown in Figure 6a.

Although a minimum 700 to 750 mm of annual rainfall is traditionally regarded as necessary for low-risk plantation forestry investment for *Pinus* *radiata*, Booth and Jovanovic (1991) consider 650 mm to be acceptable. This was the minimum rainfall threshold used in this study.

While Booth and Jovanovic (1991) identify the minimum rainfall for *Eucalyptus nitens* as 750 mm, SFNSW experience supports Landsberg, Jones, and Pryor (1990) recommendation of 850 mm as the minimum requirement: this higher threshold was used in this study.

## 1.4 DEFINITIONS

### 1.4.1 Plantations

An area of land on which the predominant number of trees forming, or expected to form, the canopy are trees that have been planted (whether by sowing seed or otherwise) for the purpose of timber production (definition from the *Timber Plantation (Harvest Guarantee) Act, 1995*).

The National Forest Policy Statement (1992) uses a definition of "*intensely managed stands of trees of either native or exotic species, created by the regular placement of seedlings or seed"*.

### 1.4.2 Land

The term ‘land’ is used in the general sense. It includes not only the soil, but the other physical attributes of the site such as the topography, climate and the existing vegetation.

### 1.4.3 Land capability

Land capability is the assessment of land for a range of broadly defined uses such as cropping, grazing or forestry. Land capability assessment aims to classify land according to its biophysical limitations. It is used to develop recommended land uses compatible with the long term sustainable use of the land (Noble 1992a).

Land capability assessment does not include consideration of the social or economic evaluations of the various uses (these are considered in land suitability, defined below).

### 1.4.4 Land suitability

Land can be classified by dividing it up into reasonably homogeneous areas based on its suitability for a particular purpose. Land suitability is defined by the Food and Agriculture Organisation (1976) as "the fitness of a given type of land for a specified use". The concept of land suitability is only meaningful if the use is specified (Food and Agriculture Organisation 1983).

Land suitability includes evaluation of the social and economic factors relating to the specified land use. As indicated in the definition of land capability, two areas of land may have the same capability class but be in different land suitability classes due to economic factors such as distance to market or land parcel size.

### 1.4.5 Availability

Land may not always be available for a particular use. For example, private land with remnant vegetation may be unavailable due to NSW State Environmental Planning Policy No. 46 (SEPP 46) clearing controls. Consideration needs to be given to the potential conflict with other land uses and to the political and social implications of various options.

# 2. POLICY CONTEXT

## 2.1 BACKGROUND

The National Forest Policy Statement (NFPS) (Commonwealth of Australia 1992) encourages the expansion of the plantation base by industrial growers and, where appropriate, by public forest agencies. Australian States have varying policies on the clearing of native vegetation for plantations. This reflects, in part, the great differences in the past history of land clearance between the States. In New South Wales, this land clearance is controlled through the SEPP 46 legislation.

The National Plantations Advisory Committee (1991) considered that there were substantial areas of land available for plantation expansion nationally. The terms of reference for that study concentrated on eucalypt plantations and were limited to consideration of cleared agricultural land, including land containing minimal areas of impoverished forest (Booth and Jovanovic 1991).

The Commonwealth, State and Territory Governments attach the utmost importance to sustainable management of Australia’s forests. In order to achieve the full range of benefits that forests can provide now and in the future, the Governments have come together to develop the Ecologically Sustainable Development National Strategy (Commonwealth of Australia 1991) a strategy for the ecologically sustainable management of Australia's forests. The strategy and its policy initiatives will lay the foundation for forest management in Australia into the next century.

## 2.2 COMMONWEALTH

### 2.2.1 National Forest Policy Statement

The 1992 NFPS is the joint response of the Commonwealth, State and Territory governments to three major reports on forest issues- those of the Ecologically Sustainable Development Working Group on Forest Use (1991), the National Plantations Advisory Committee (1991), and the Resource Assessment Commission’s Forest and Timber Inquiry (1992)- and it builds on the 1983 *National Conservation Strategy for Australia* initiated by the Commonwealth Government and the 1986 *National Forest Strategy for Australia* developed by the Australian Forestry Council.

The Statement was developed by the Commonwealth, States and Territories through the Australian Forestry Council and the Australian and New Zealand Environment and Conservation Council in consultation with other relevant government agencies, the Australian Local Government Association, unions, industry representatives, conservation organisations and the general community. The statement was signed by all participating Governments, with the exception of Tasmania, at the Council of Australian Governments’ meeting, held in Perth in December 1992. Tasmania became a signatory to the Statement on 12 April 1995. The Statement has been developed concurrently with the development of the Ecologically Sustainable Development National Strategy (1991) and the National Greenhouse Response Strategy (1992).

The NFPS has the following objectives in relation to plantations:

- Increasing commercial plantation development on cleared agricultural land and, where possible, integrating plantation enterprises with other agricultural land uses;
- Increasing productivity of existing plantations, through improved technology, genetically improved stock, and selection of the best species and provenances;
- Encouraging industrial growers, and where appropriate, public forestry agencies to expand their plantations, to satisfy specific requirements; and
- Integrating plantation enterprises with other agricultural land uses.

The NFPS also gives direction on economic, environmental and social issues pertaining to plantations, and identifies the important role of industry. Its key directives/agreements in this regards are:

- The establishment of plantations for wood production should be based on their economic viability; and
- State and local governments will provide a planning framework that facilitates the development of large-scale industrial plantations; and
- Consistent with ecologically sustainable management objectives, the States should not clear public land for plantations, where this would compromise regional conservation and catchment management objectives.

### 2.2.2 Wood and Paper Industry Strategy

Following the NFPS, the Commonwealth introduced the Wood and Paper Industry Strategy (WAPIS) (Commonwealth of Australia 1995), with the following objectives:

- To expand plantations and associated processing industries and promote full utilisation of the plantation resources;
- To develop large regional plantation and commercial farm forestry resources to provide reliable, high quality supplies of wood for world scale industries, plus associated landcare and environmental benefits; and
- To expand regional opportunities for employment in the plantation industries.

Challenges identified for the implementation of this strategy were:

- Identifying and removing impediments to plantation investment;
- Promoting plantation development on cleared agricultural land;
- Establishing farm forestry as an integral part of the plantation program;
- Improving research and development on plantations, including commercial farm forestry; and
- Promoting public access to information on plantations and farm forestry and their place in the wood and paper industry.

Together, the NFPS and WAPIS provide a sound political base for expanding Australia's plantations, but investment has been limited. According to Ferguson (1997), this is poised to change as a result of work at State and local levels to remove disincentives to plantation investment, including freeing the sector from export controls. Nevertheless, there is still a feeling of unease in the eastern States, despite the downturn in profitability of the grazing industry - which is a major competitor for land. Ferguson points out that structural adjustment issues favour a change in land use, and that the European Union's recent commitment to reducing greenhouse gas emissions should add momentum to further plantation establishment.

## 2.3 PLANTATIONS 2020 VISION

In July 1996, the Ministerial Council for Forestry, Fisheries and Aquaculture endorsed a proposal by industry for trebling the plantation estate by the year 2020. To achieve this goal, the Council agreed to develop a realistic and achievable national strategy, in consultation with relevant stakeholders.

A draft implementation plan, commissioned by the Standing Committee on Forestry (SCF) and developed by the Centre for International Economics, was used as the basis for the preparation of an implementation plan entitled "Plantations for Australia, The 2020 Vision". This plan was released on 2 October 1997. Fully implemented, the Vision could provide the following outcomes:

- an additional $3 billion in investment in Australia's plantation industry between now and the year 2020;
- substantially assist in converting the nation's $2 billion trade deficit in wood and wood products into a trade surplus;
- revitalise rural economies through jobs growth and increased farm income; and
- create up to 40 000 new jobs nationwide in forestry, logging, processing and flow-on industries such as transport.

The 2020 Vision implementation plan lists four strategic imperatives, 11 goals and 28 actions to implement the Vision. The strategic imperatives are:

1. Boost the availability of suitable land;

2. Get the commercial incentives right to enhance the development of the plantation growing and processing industry;
3. Establish a commercial plantations culture; and
4. Improve information flows.

Action four of the first strategic imperative is of particular relevance to this study, because the goal is to:

*'Improve widespread knowledge of the regional potential to grow trees, and of the species and production techniques that suit the land base and meet the market demand'*.

The two actions required to achieve this goal are:

1. the identification of suitable land and the existing resource base; and
2. to ensure that research and development is nationally coordinated and strategic.

## 2.4 STATE

The New South Wales Government is a signatory to the NFPS and the Plantation 2020 Vision and as such has agreed to be bound by their provisions, including the expansion and facilitation of plantation development.

Additionally, the New South Wales Government has a forestry policy (March 1995) which sets targets for plantation establishment by SFNSW of:

1. establishment of 10 000 ha of eucalypt plantations in 1997-98; and
2. doubling the size of the softwood plantations (currently about 200 000 hectares).

The policy also involves enhancing existing share farming arrangements for hardwood plantation establishment. An increase in the commitment to research and development, which includes enhancing productivity with genetic development and fertilisation programs for plantations, is also part of the policy.

The 5000 ha target for eucalypt plantations in 1996-97 was achieved with the planting program combining establishment on SFNSW' own land and joint ventures with landholders; the latter where SFNSW plants the farmer's land.

The New South Wales Government's commitment to plantation development has also led to the *Timber Plantations (Harvest Guarantee) Act, 1995*. The purpose of this Act is to encourage investment in plantation development, particularly in the private sector, by providing greater security for future investment. This would be achieved by ensuring harvesting rights of bona fide timber plantations.

The State Government has also formed alliances with industry in the form of Memoranda of Understanding (MOU's) which commit to the establishment of additional plantation areas strategically located near new industrial developments such as the proposed VISY Industries development in southern New South Wales. In order to ensure environmental standards are followed, SFNSW introduced Part 1 and Part 4 of the Forest Practice Code which cover plantation harvesting and plantation establishment.

At a local government level, several councils in the south west slopes region of New South Wales have joined with the local branch of Australian Forest Growers in the development of a Code of Practice to facilitate local government approvals for plantation establishment and subsequent harvesting. In the north, the Department of Land and Water Conservation (DLWC) and SFNSW have developed the "Erosion and Sediment Control Strategy for Eucalypt Plantation Establishment on the North Coast of New South Wales" to facilitate planning for hardwood plantation establishment.

Regional Development Boards have also been active in encouraging councils to adopt a uniform and positive approach to plantation development.

## 2.5 PROFILE OF DOMESTIC AND GLOBAL MARKETS

The area of Australia's plantations was estimated at 1.043 million hectares to the end of 1994 ( National Forest Inventory 1997a). - Estimates of yield for the year 2010 vary considerably (Turner & James 1997), ranging from 18.1 million $m^3$ (Clark 1995), to 13.5 million $m^3$ (New Zealand Ministry of Forestry 1995). Turner & James (1997) provide a figure in between these at 17.3 million $m^3$. The figure rises to approximately 20 million $m^3$ by 2020 (National Forest Inventory

1997). These predictions are based on confidential data from producers, on the area and age structure of existing plantations, plus projected increases in the area of new plantations in the medium term (NFI 1997), estimated at some 20 - 40 000 ha $year^{-1}$ (e.g. James et al 1995; Centre for International Economics 1997).

### 2.5.1 Domestic market - total forest products

Projections of domestic demand for forest products indicate that the existing domestic trade deficit may continue into the next century, though it will start to reverse, and should turn around into a surplus by about 2005, due to increased domestic production. Australia has had a trade deficit of about two million $m^3$ $year^{-1}$ (RWE[1]) since World War 2 (James & Turner 1995), but Neufeld (1997) predicts a net surplus in softwood sawn timber trade by 2005-6, reaching around 0.8 million $m^3$ by 2010-11. The trade deficit in hardwood sawn timber is also expected to slowly reduce, approaching a net balance by 2010. Under this scenario, an average annual surplus of approximately 0.7 million $m^3$ of sawn timber in the period 2005 - 2010 is projected. The domestic market for paper and fibre based products is expected to mirror this trend (Neufeld 1997).

### 2.5.2 Domestic market - plantation products

Despite the projected growth in exports and import substitution, Australia is likely to experience a net deficit in the overall trade of plantation products into the next century, (Neufeld 1997), which, based on new plantings of up to 40 000 ha per year, is estimated at around 1.3 million $m^3$ $year^{-1}$ (RWE) by 2015 (James et al 1995).

### 2.5.3 World market - forest products

World consumption of industrial wood is expected to increase by about 81 million $m^3$ $year^{-1}$ from about 1993 to 2010 (FAO (1995) in Ferguson, 1997). At the end of this period, total consumption is estimated at 2.28 billion $m^3$ $year^{-1}$. Over this period supplies of tropical timber from Malaysia and Indonesia are expected to decline significantly, by up to 30 million $m^3$ $year^{-1}$, (Johnson 1997; De Fégley et al 1997). Additionally, wood supply from the Pacific North-West of the United States and British Columbia in Canada is presently 50 per cent of the rate prior to the introduction of supply restrictions in the late 1980s, related to conservation of spotted owl habitat. It is estimated that supply will remain significantly below past levels (Ferguson 1997).

The combination of projected global economic growth, and increased protection of native forests, is expected to cause shortfalls in the supply of forest products, which Ferguson (1997) estimates will be around 93 million $m^3$ $year^{-1}$ in softwood, and 48 million $m^3$ in hardwood, by 2010. The deficit in the Asia Pacific region alone is estimated at around 60 million $m^3$ by 2010 (De Fégley et al 1997). However, as Ferguson points out, the predicted global shortfall in wood supply is less than 5 per cent of total consumption, and is predicated on the currently significant, but potentially unstable economies of China, India and Indonesia. Furthermore, should the shortfalls occur as predicted, then wood prices would rise, causing substitution by non-wood products, plus products derived from logs of lower quality (Ferguson 1997; De Fegley & Meynink 1997).The present analyses strongly indicate that the value of wood products will rise, in response to increasing scarcity of high quality wood resources, especially in the Asia Pacific region.

[1] Round Wood Equivalent - a common unit of unprocessed round wood needed to produce a given quantity of forest product. Allows comparison between different forest products.

# 3. EXISTING PLANTATIONS

## 3.1 LOCATION

Figure 6a shows the location of existing plantations in the Eden Study Area (refer Section 1.3 for a definition of the Eden Study Area). There are 35 510 ha of commercial plantations in the Eden Study Area, of which 1070 ha are hardwood (including 300 ha of farm forestry woodlots) and 34 390 ha softwood species concentrated in the SFNSW Bombala Management Area. SFNSW have a further 300 ha of hardwood plantation trials in the Eden study area, however, these are not included as potentially merchantable resource.

As indicated in Table 3a, softwood plantations dominate the plantation resource. The dominant species is *Pinus radiata* which constitutes 97.7 per cent of the total area. *Eucalyptus nitens* is the major hardwood species.

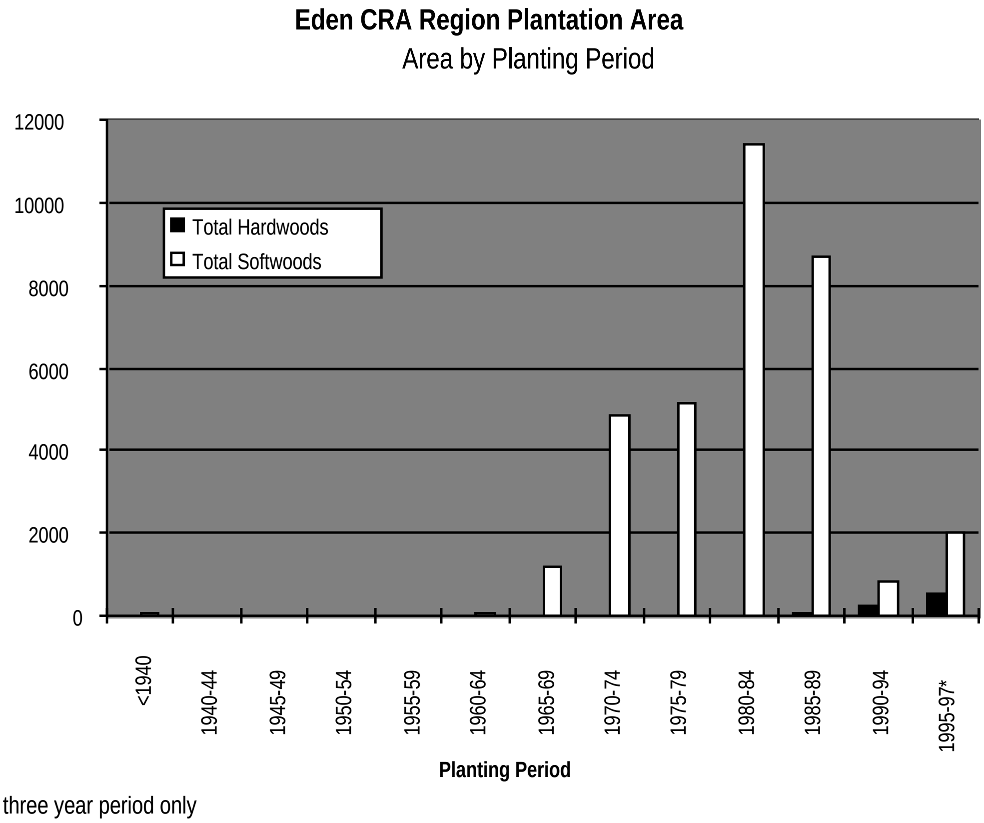
**TABLE 3A: PLANTATION SPECIES AND AREA (HA) IN THE EDEN CRA REGION**

| Species | Hectares (ha) |
|---|---|
| *Eucalyptus nitens* | 700 |
| *Eucalyptus globulus* | 40 |
| Woodlots | 300 |
| Other hardwoods | 30 |
| ***Total Hardwood*** | ***1070*** |
| *Pinus radiata* | 34 390 |
| Other softwoods | 50 |
| ***Total Softwood*** | ***34 440*** |
| **REGIONAL TOTAL** | **35 510** |

(National Forest Inventory 1997)

There has been a progressive increase in the areas of softwood plantations established since the late 1960s, peaking in the 1980-84 planting period which is abnormally high due to the replanting of resource lost in the 1983 wildfires (see Figure 3a). The areas planted in the subsequent decade are much lower, however, the 1995-97 period indicates an increase in the areas planted to softwoods. Both Willmott Forests Pty Ltd. and SFNSW report continued softwood planting programs over the next few years (Willmott pers.comm. SFNSW pers.comm.). There is a small but increasing area of hardwood plantations, planted since the second half of the 1980s.

*Figure 3a: Areas of hardwood and softwood Plantation by planting period*




(National Forest Inventory 1997a)

## 3.2 PRESENT AND FUTURE VOLUMES

**TABLE 3B: SOFTWOOD RESOURCE VOLUMES FROM PLANTATIONS IN THE EDEN CRA REGION (SOURCE SFNSW)**

| | sawlogs ($m^3$) per annum | pulpwood roundwood (tonnes) per annum | sawmill residues (tonnes) per annum |
|---|---|---|---|
| current harvest | 50 000 | 35 000 | 0 |
| potential 2002 [a,b,c] | 290 000 | 200 000 | 87 000 |
| potential 2010 [a,b,c] | 380 000 | 270 000 | 114 000 |
| potential 2020 [a,b,c] | 550 000 | 270 000 | 165 000 |

a) Potential 2002 level of yield based on current plantation resource; potential 2010 and potential 2020 levels of yield assume an expansion of the total plantation estate by 10,000 ha and 20,000 ha respectively.

b) Sawlog availability predicated on the sale of all pulpwood and sawmill residue.

c) Potential yields represent sustained annual levels assuming an even distribution of age classes (which is not currently the case).

Table 3b explains the potential yields from the current and expanded plantation estate. The expansion of the plantation estate is based on an approximate expansion of 1000 hectares per year. The potential 2002 is based on the current plantation resource. Additional plantings from 1998 to 2002 will have no influence on timber availability at 2002 given their lack of merchantable product.

The case for the label "potential 2002" compared with "current potential" in Margules, Poyry (1997) industry development options report, is based on the fact that the earliest recognised industry development option is for a mill processing 300 000$m^3$ in 2002. For this reason the label "current potential" in the Margules report could be considered misleading.

# 4. DATA REVIEW

## 4.1 PURPOSE

The purpose of the data review was to ensure that all available information was considered in undertaking this project.

The review was undertaken in two parts:

- a review of existing literature and relevant reports; and
- a review of the data required for this project.

The data review is described in more detail in the following sections.

## 4.2 REVIEW OF LITERATURE AND RELEVANT REPORTS

Appendix 1 provides a tabulated audit of relevant literature reports on plantations. The review extracts information such as: the area these studies covered; the species considered; the datasets used; and the type of analyses undertaken. This information was used as a reference source for the project.

It should be noted that the previous studies have not used the same boundaries as used for this study.

The following sections highlight the studies that are most relevant to the Eden Study Area. Study areas covered, the data used, the analyses undertaken and the overall limitations of the studies in terms of what this plantations project aims to achieve are discussed in these sections.

### 4.2.1 Review of Jurskis (1996)

SFNSW' Geographic Information System (GIS) was used to delineate and tabulate areas of land potentially suitable for timber plantations.

#### The study area

Subject to some limitations of data availability, the study generally covered the south eastern area of New South Wales. The potential of land in adjoining areas of Victoria between the State border and the Victorian town of Cann River was also considered.

#### Methodology applied

The primary criteria (GIS data) adopted were:

- annual mean rainfall of 750 mm for softwood and 900 mm for eucalypts were specified as the minimum requirements (Source data: Annual Mean Rainfall Isohyet Map, CSIRO, 1:500 000);
- slopes generally less than $18^0$ (Source data: Department of Land and Water Conservation, land capability mapping, 1:100 000); and
- land which was essentially cleared with only scattered remnants of native vegetation (Source data: NPWS Eastern Bushland Database, 1:250 000).

The secondary criteria (drawn from 2.5 days of field inspections) adopted were:

- minimum soil depth of 1000 mm to solid rock or 650mm to claypan or water table;
- a dominant height of native vegetation exceeding 25m;
- observations of existing woodlot or windbreak plantings recorded;
- obvious socio-economic factors relating to land use noted; and
- discussions and field inspections with ACT Forests.

The GIS data were used to delineate and tabulate areas meeting the slope and vegetation criteria in the following rainfall classes: <600mm, 600-700mm, 700-750mm, 750-800mm, 800-900mm and >900mm. The areas south of the Victorian Border to Cann River were delineated manually on 1:100 000 topographic maps, areas were estimated using a dot grid, and no field inspections were carried out.

#### Limitations

The limitations of this study were:

- that it was only a physical capability assessment;
- the coarse scale of datasets used in the mapping;
- that it only involved a cursory examination of soils (2.5 days of field inspections);
- that the study did not quantify yields; and
- that the study did not address economic, social and market aspects in any detail.

### 4.2.2 Review of Landsberg et al (1990)

This study estimated the area of land suitable for eucalypt plantations in south east New South Wales.

#### The study area

The study area incorporated Delegate to Nimmitabel and covered Bombala and Bega Valley Shires.

#### Methodology applied

The primary criteria adopted were:

- rainfall zones >850mm;
- slopes <15°;
- rateable land; and
- a basic economic analysis.

#### Limitations

The limitations of the study were that there was:

- no consideration of soils/geology (except for a written description);
- no consideration of economic and market aspects;
- no data sources specified;
- no land value used; and
- no maps produced.

### 4.2.3 Review of Stanton (1990)

This study estimated land suitability for eucalypt plantations.

#### The study area

The area studied was south east New South Wales, latitude 36°30’S and longitude 149°00’E.

#### Methodology

The methodology adopted for this study involved:

- grid resolution of 9 seconds (approximately 250m x 250m (6.25ha or 1:500 000 scale));
- cleared land;
- slope <15°;
- rainfall > 850mm up to 600m elevation (BIOCLIM package);
- rainfall > 750mm over 600m elevation (BIOCLIM package);
- potential nutrient supply index at least 5 out of 10; and
- mapped using GEOPAK.

#### Limitations

The limitations of this study are:

- the large grid size of 250m x 250m;
- that no economic analysis was undertaken; and
- that it is now out of date.

### 4.2.4 Review of Booth and Jovanovic (1991)

This was a broadscale study for the National Plantations Advisory Committee which looked at a broad range of species and requirements.

#### The study area

This was a national study.

#### Methodology applied

The criteria applied to this study were:

- rainfall >600mm/year;
- cleared vegetation;
- dry season <6 months;
- low to moderate relief; and
- deeper, well structured soil.

#### Limitations

The study used a 3 minute grid (correlates to a 5 km spacing or 1:12 000 000 scale) and therefore while it was an important national study, it was undertaken at too small a scale for use in this project.

## 4.3 DATA REQUIRED FOR THE PROJECT

Appendix 2 details the data required to undertake this project, the data that is currently available, any data gaps/limitations in the existing data and actions required to address these gaps/limitations.

## 4.4 CONCLUSION - DATA OVERVIEW

Land capability and suitability work have previously been undertaken in the Eden region. These studies have been conducted for various purposes, not all of which suit this project. Limitations of existing work included:

- that some of the work was limited to land of marginal utility for agriculture;
- that they did not cover the full CRA Regions as now proposed;
- that they were undertaken without comprehensive current knowledge of remnant native vegetation;
- that they did not all take a comprehensive view of topographic factors; and
- that they did not all attempt to classify sites according to their potential productivity for plantations; and

This project enables consistent analysis to be undertaken throughout New South Wales and covers areas of capability, suitability and economic analysis which has not been undertaken in any previous study.

# 5. CONCEPT OF PLANTATION CAPABILITY

Land capability assessment involves an examination of land, for a particular purpose, taking into consideration biophysical factors, but ignoring socioeconomic implications. It aims to define the intrinsic, or potential capacity of land to support sustained, defined uses, such as tree cropping with specified species and management inputs. The United States Department of Agriculture (USDA) land capability classification system is an example.

Plantation capability assessment, therefore, identifies areas that are capable of supporting particular tree species. In other words, it identifies locations where the biological growth requirements of the species under consideration are satisfied. Typically, the process involves comparing a set of edaphic, climatic and topographic parameters of different sites, against the specific biological requirements of different species. Since different species have different biological needs, it is important to define a list of requirements for each species as a basis for the iterative spatial matches, performed using GIS. In a simple analysis, land may be deemed capable or incapable, based on the interactions of thresholds of various parameters - or the effect of a particular factor determined to be most limiting to growth (Hackett 1988). In more complex analyses, locations may be given a capability rating, to indicate levels of potential growth and yield, such as site index.

## 5.1 PLANTATION CAPABILITY

The plantation capability study covered six stages:

1. Reviewing methodology and findings of existing studies; identifying information gaps; developing an appropriate methodology.
2. Identifying species for consideration, and collating data on their environmental requirements for growth and yield information from existing plantations within the Eden Study Area.
3. Defining environmental requirements for selected species, and identifying and selecting specific environmental variables that are related to plantation growth.
4. Collating and developing the selected environmental variables within a GIS environment.
5. Identification of exclusions where plantation assessments were not to be undertaken.
6. Estimation of site quality for selected species across the entire Eden Study Area using a combination of rule-based and statistical techniques.

The preceding chapter discusses the methodology and findings of existing studies.

## 5.2 SPECIES SELECTION

Selection of appropriate tree species for plantation depends upon:

1. the purpose of the plantation (e.g. investment, land rehabilitation);
2. type(s) of product desired (e.g. fibre, timber, fodder, firewood, amenity);
3. availability of markets in the future;
4. biological requirements of the species; and

5. availability of management and research data for the species under consideration.

A list of species to be assessed for plantation potential was developed in accordance with the criteria listed above. The findings of other relevant studies were also drawn upon, - a brief literature review is provided in Appendix 1. Together, this information led to the assumptions discussed in Sections 5.3.1 to 5.3.5.

### 5.2.1 Purpose of the plantation

For the purposes of this assessment, land capability relates to a variety of proven species, suited to medium-to-large scale plantations or wood-lots, for production of fibre and solid timber products. This is because it is difficult to obtain reliable, quantitative data on the biological requirements of other possible species for the Eden Study Area. It is assumed, however, that areas capable of supporting high-yielding eucalyptus species preferred for industrial use, would also support a variety of species for other purposes.

### 5.2.2 Desired products

A range of products could be obtained from plantations in the Eden Study Area but the main emphasis of the capability study was on timber and fibre production. If land is assessed as being able to support plantations for timber and fibre production, it is assumed that it could also support plantations for other purposes, such as environmental protection, shelter, firewood, farm poles etc., either exclusively, or as by-products of the primary production objective.

### 5.2.3 Markets

Future demand for plantation timber from the Eden Study Area will be strongly influenced by the size and characteristics of the existing plantations and native forests. Consequently, the preferred plantation species are *Pinus radiata* for long softwood fibre and timber, and *Eucalyptus nitens* for hardwood fibre and timber production (see Section 5.3.6).

### 5.2.4 Availability of research

Generally, there is a lack of detailed information on the biological requirements and growth rates of different tree species within the Eden Study Area. With regard to the estimation of yield, the focus of this capability study was therefore limited to those species for which growth data are available.

### 5.2.5 Principal species in existing plantations

Existing softwood plantations within the Eden Study Area are almost exclusively *Pinus radiata*, with *Eucalyptus nitens* making up over 90 per cent of existing hardwood plantations. *E. globulus* makes up a further 5 per cent, with the remainder being a mixture of species.

A number of species have been trialed within and around the Eden Study Area including:

- *E. agglomerata;*
- *E. badjensis;*
- *E. globulus spp.;*
- *E. cypellocarpa;*
- *E. delegatensis;*
- *E. dunni;*
- *E. fastigata;*
- *E. fraxinoides;*
- *E. viminalis;*
- *E. globoidea;*
- *E. laevopinea;*
- *E. muellerana;*
- *E. nitens;*
- *E. obliqua;*
- *E. radiata;*
- *E. regnans; and*
- *E. smithii.*

A summary of these species trials can be found in Johnson and Stanton (1993).

For most of these species, however, there is insufficient quantitative information to describe species responses to changes in environmental conditions across the Eden Study Area.

### 5.2.6 Selected species

A workshop was held on June 4, 1997 to discuss a range of issues relating to the project. The workshop included representatives from SFNSW, DLWC, the Bureau of Resource Sciences (BRS), Australian Bureau of Agricultural Resource

Economics (ABARE), Plantations Australia, Greening Australia and Southeast Conservation Council. Taking into consideration other studies, plantation trials, assumptions about demand, market preference and availability of accurate data, the workshop decided that *E. nitens, P. radiata, E. botriodes, E. globulus and E. maculata* should be considered for the assessment.

Following detailed discussions with other representatives present at the workshop in relation to the quality of available growth and yield information, SFNSW recommended the following two species.

- *Pinus radiata*; and
- *Eucalyptus nitens.*

Information at the time suggested that sufficient data were available on growth rates and responses to climatic and edaphic variation for these species, to make quantitative estimates of productivity, based on a prescribed set of site variables.

## 5.3 FACTORS AFFECTING PLANTATION GROWTH

Four factors largely determine the growth and yield of plantations, namely:

1. Site environmental conditions (climate, soils and topography);

2. The extent to which the site is utilised or occupied. This is largely synonymous with the term stand density or stocking;

3. Cultural or management treatments (pre-establishment site preparation, tending, fertilising, pruning, thinning, etc.) and

4. Genetic makeup of planting stock.

Given the scale and resolution of this study it was not possible to account for the influence of the last three factors on potential plantation growth. The following assumptions were made about these factors:

- silviculture is standardised. This means that possible improvements to productivity through e.g. site preparation, espacement and fertilising were assumed identical.
- possible benefits through use of superior genetic stock or use of cuttings versus seedlings were assumed identical.

Environmental influence on potential plantation growth and yield is exerted through the interaction of the following factors:

- climatic factors (e.g. rainfall, air temperature, humidity, solar radiation and wind);
- soil factors (e.g. physical and chemical properties, water holding capacity and soil microorganisms) and
- topographic factors (e.g. slope, aspect and specific catchment area).

Rainfall and its distribution in space and time not only affects tree growth potential but survival as well, particularly during early years following establishment. Without irrigation, the amount of water available for plant growth is a balance between the rain actually falling and that lost through interception by plants, evaporation from both plants and soil surface, surface run-off and underground drainage. Additional moisture may also be made available through underground water movement. With regard to moisture, it is also important to note that some plantation species, e.g. *P. radiata*, are known to cope better with longer dry periods than others.

Plant growth responses to temperature are complex and dynamic. Plants will not grow if temperature conditions are not suitable, even though other conditions such as radiation and water may be favourable. As well as influencing patterns of growth, extreme temperatures may damage or even kill trees. However, slow introduction of most plants to low temperatures is known to ‘harden’ them or improve their ability to withstand colder conditions than if temperatures drop rapidly.

Solar energy is required to drive the process of photosynthesis. The amount of radiation available for plant growth is influenced by the incident radiation and the plant’s ability to intercept that radiation. Weather conditions, season, aspect, slope and surface properties impact on the incident radiation.

Soil factors such as texture and depth have a major influence on potential moisture storage and retention capacity of a site. These soil physical properties also influence the ability of roots to explore a site for nutrients. Soil physical properties are particularly important as they are difficult to modify, unlike chemical factors which can be easily improved by fertiliser application for instance. Chemically, the levels of phosphorous, nitrogen and potassium in the soil are particularly critical to plant growth. A good balance of trace elements is also essential.

Interaction between the various environmental factors also influences tree growth. For example, radiation, temperature and aspect interact to exert an influence on plant growth by impacting on potential evaporation at a site. Topography and soil factors interact to create micro-climates impacting on plant growth. Climate, topography and soil factors interact to exert an influence on growth by impacting on a site's moisture balance. In Australia, low moisture and adverse soil properties, such as shallow and ancient soils, are considered to be the major causes of low site productivity.

Species environmental conditions thresholds adapted from Booth and Jovanovic (1991) are in Appendix 3.

## 5.4 COLLATION AND DEVELOPMENT OF VARIABLES WITHIN GIS

The following environmental data (refer tables 5a to 5c) were either already available or developed using GIS for this study.

**TABLE 5A: CLIMATE DATA**

| | |
|---|---|
| Monthly and annual rainfall | These data were generated by ESOCLIM[2] at 100 metre raster resolution. |
| Monthly and annual mean minimum and maximum temperature | Generated by ESOCLIM at 100 metre raster resolution. |
| Radiation (short wave, long wave and net) | Generated by SRAD[3] at 25 metre raster resolution. Calculation of radiation takes into account terrain, sunshine fraction, cloud transmittance, albedo or electromagnetic reflectance, average radiation and temperature. |
| Monthly and annual potential evaporation | Generated by SRAD at 25 metre raster resolution using the equation: $E = R(0.01768 + 0.0007585T - (0.00000605T^2))$ where R is net radiation and T is SRAD average temperature. |

**TABLE 5B: SOIL DATA**

| | |
|---|---|
| Geology | Geology data for whole area provided at 1:250 000 by NSW Department of Mines |
| Lithology | Lithology data for whole area were provided at 1:250 000. This was based on CSIRO interpretation of the geology layer referred to above. |
| Soil landscapes | Available for two 1:100 000 mapsheets only, Bega and Eden. The landscape units included the following attributes: texture (top and sub soil), depth (upper, mid and lower slopes), stability, water holding capacity and fertility. The soil landscapes were provided by DLWC. |
| Soil depth | Soil profile depth for each soil unit was interpolated across the landscape using a topographic index derived from the digital elevation model which defined the spatial extent of upper, mid and lower slope terrain elements. Dominant lithology was then used to extrapolate landscape units and soil depth to areas not covered by soil landscape mapping, i.e. Bombala and Craigie 1:100 000 mapsheets. |

[2] ESOCLIM- Program developed to estimate long term mean monthly values of climatic variables (McMahon et.al. 1997).

[3] SRAD - Program developed to estimate solar radiation (Gallant, J. 1996).

| | |
|---|---|
| Nutrient index | A three class fertility classification of the soil landscapes units was developed using soil chemistry and geo-chemical information. Dominant lithology and geo-chemical data were used to extrapolate this attribute to areas not covered by soil landscape mapping, i.e. Bombala and Craigie 1:100 000 mapsheets. |

**TABLE 5C: TOPOGRAPHY DATA**

| | |
|---|---|
| Slope, aspect , elevation, flow-width, plan curvature and upslope contributing area | Derived from a 25 metre DEM provided by the Land Information Centre (LIC). |

## 5.5 EXCLUSIONS

This study recognises that any new plantation establishments would have to be confined to cleared private land. This is in accordance with the *State Environmental Planning Policy No. 46* (SEPP 46) which restricts clearing of native vegetation on freehold land across the state.

BRS generated a dataset distinguishing between forested and non-forested land for the Eden Study Area from two datasets. For areas within the Eden CRA boundary, the NPWS's woody vegetation dataset was used. For areas outside the Eden CRA boundary, the NPWS' Eastern Bushlands dataset was used. A forest was defined as a treed stand of greater than 20 per cent crown cover in both datasets. It should be noted, however, that even though scattered open woodland communities were mapped as non-forest in both datasets, they cannot be cleared, without permission, for plantation purposes under present provisions of SEPP 46.

SFNSW plantation establishment regulations do not permit ground disturbances associated with forestry activities on areas within the proximity of streamlines and major roads. The specifications listed in the booklet *SFNSW Forest Practices Code Part 3 - Plantation Establishment and Maintenance* (July 1997) were adopted as the standard for this project. The minimum widths of protection zones along drainage features are:

- Major water storages - 100 metres;
- Prescribed streams, watercourse and wetlands - 20 metres; and
- Drainage lines and drainage depressions - 5 metres.

Where Road Transport Authority (RTA) or council roads exist, plantation establishment is not permitted on areas within 30 metres from the centre of the road (Charlie Taylor, SFNSW Bombala - pers.comm.). These strips form fire breaks as well as roadside reserves. LIC streamlines were used to define areas within stream proximity. AUSLIG TOPO-250K (1994) data were used to identify the major roads.

All areas meeting the above criteria were considered unavailable for plantation establishment and therefore their plantation potential was not considered in the analysis. The following list is a summary of the exclusions:

- public lands;
- private forested lands;
- residential - town and rural;
- areas within 25 metres of major roads; and
- areas within 25 metres of prescribed streams.

## 5.6 ESTIMATION OF SITE QUALITY - MODELING METHODS

Before describing the modeling methods, the concept of site index will be briefly introduced.

Site index is defined herein as stand mean dominant height in metres at age 20 years. The height is based on the average height of the tallest 40 trees per hectare. Where a stand has not reached age 20, tree height versus age curves applicable to the region of interest are generally used to estimate site index. Tree height is strongly and positively correlated with tree volume. Given the relationship between tree height and tree volume, it is not unreasonable to assume that a similar relationship exists between volume and site index.

The volume of products from a particular site and their ability to meet requirements for a specific use are generally used as a measure of site quality. Site quality is not an easy thing to assess because site environmental factors and the plants themselves are interacting and interdependent, making it difficult to assign cause and effect relationships. In this study, product quality is not considered in determining site quality due to lack of information relating site to product quality. Suffice to say, although for the most part ex-pasture sites are generally highly productive when planted to trees, there are many instances where *P. radiata* trees on these sites have developed a poor form characterised by heavy branching and severe stem deformation, a condition termed "speed wobbles" in forestry. This is often attributed to high residual fertility, a legacy of previous fertilizer application.

Four general approaches may be used to categorise sites into productivity classes:

1. quantitatively based on site productivity (e.g. volume production at specified age);

2. quantitatively based on site index (e.g. predominant or top tree height at a specified age);

3. qualitatively based on naturally occurring vegetation or land form; and

4. qualitatively based on climate.

In production forestry, a good indicator of site quality is one that is highly correlated with the ultimate measure of site productivity, volume, while at the same time being largely unaffected by stand density and past management practices. It should also be easy to measure and accurately delineate areas of different productivity for a given species. Tree height meets these criteria well and where suitable data are available, site index should generally be the preferred approach to delineate sites for plantation purposes (ANU, 1989). Volume yield is sensitive to past management practices, for example, initial stocking and thinning, and therefore is not a very good indicator of site quality.

Classification on the basis of naturally occurring vegetation is based on the theory of Cajander (1926) that certain key species (indicator plants) in the forest reflect the overall quality of a site for a tree species or forest type. This is not an unreasonable expectation considering that the species composition of understorey vegetation present on a given site commonly reflects fertility of the soil and is often a good indicator of the availability of soil moisture in the upper soil horizons.

Of the climatic variables, rainfall is probably the most used in categorising site productivity. However, rainfall per se has limited use in categorising site productivity in that its effectiveness for tree growth is largely dependent on its interaction with soil type, topography and other climatic variables. Nevertheless, where soil type, topography and other climatic variables are favourable, increases in site productivity may be observed with increases in rainfall. This is generally true provided no water logging occurs.

For this study, in addition to the environmental data (refer to section 5.4), different site quality data for each species were available. In particular, site index data were available for *P. radiata* plantations. No site index data were available for *E. nitens*. However, modeled pre-European vegetation type data were available and used as a proxy for *E. nitens* site quality. The nature of these data dictated that different modeling methods be used for each species.

### 5.6.1 *P. radiata*

#### Site index data

NSW State Forests provided site index data for 575 compartments from their existing plantations in the Eden Study Area. The compartments were spread across the whole resource and covered many age classes. Site index, stand mean dominant height at age 20 years, ranged from 19 to 29 metres. For each site index there were a minimum of 14 and a maximum of 90 compartments, with compartments covering a range of environmental conditions. The site index data were provided digitally in vector format, with the compartment as the smallest unit. Compartments ranged in size from approximately 0.07 to 188 hectares. The original data were captured at 1:25 000 scale. Table 5D summarises the site index data.

**TABLE 5D: SITE INDEX DATA**

| Site index (m) | Number of compartments |
|---|---|
| 19 | 14 |
| 20 | 27 |
| 21 | 25 |
| 22 | 88 |
| 23 | 54 |
| 24 | 68 |
| 25 | 51 |
| 26 | 72 |
| 27 | 90 |
| 28 | 47 |
| 29 | 39 |

#### Model development

The first modeling step involved identifying all sites in the study area that did not meet the following environmental thresholds as given by Booth and Jovanovic (1991):

- mean annual rainfall equal to or greater than 650 mm,

- dry season (consecutive months receiving 40 mm or less rainfall) of less than four months.

Using the monthly mean minimum temperature surfaces, it was established that, for the existing SF plantations in the Eden Study Area, the mean minimum temperature of the coldest month was approximately -3.5° C. Areas that did not meet the requirements specified by Booth and Jovanovic (listed above) and the mean minimum monthly temperatures determined by this study (-3.5° C) were masked out or excluded from further analysis in relation to their potential to grow *P. radiata* in commercial plantations. Booth and Jovanovic recommend a mean minimum monthly temperature cut-off of -2.0° C for *P. radiata* plantations. A cut off temperature of -3.5° C, as determined by this study, was used.

The site index vector coverage was converted to a 100 metre resolution raster. Then, for all compartments, a weighted mean (weighted by cell count) value for each of the environmental variables was determined (see Appendix 4). The output from this process was a table of compartment identifier, site index and corresponding weighted mean value of the variables. Statistical techniques, using SPLUS and STATISTICA software, were then used to identify outliers and potential errors in the site index data. This process involved use of box plots and normal distribution plots to identify, for each site index and environmental variable, weighted mean variable values that were at least three standard deviations from the mean value for each site index. The compartments whose mean values fell outside the three standard deviations were subjected to further analysis to determine site index values of compartments immediately surrounding them in relation to their environmental variables values. Compartments which showed significant anomalies, for example, large sudden jumps in site index values that were not supported by similar changes in environmental variables of immediate neighbouring compartments, were regarded as errors and removed from the sample. A total of 12 compartments were identified as errors and removed.

To enable the effect of interaction between variables on site index to be examined, additional variables were derived by combining some of the variables presented in section 5.5. A moisture balance index was derived by calculating the ratio of rainfall to potential evaporation. A fertility index incorporating soil physical and chemical attributes was derived by multiplying the nutrient index with the soil depth index.

Although soils in the Eden Study Area may be a key variable affecting productivity, site index data from existing plantations did not allow statistically valid relationships between site index and soil variables to be developed. Preliminary analysis established that the existing plantations and site index data only occurred on a small number of soil landscapes that were not representative of the study area. The initial model development therefore focused on climatic variables. The method of incorporating soils data into the model is discussed further below in this section.

Using stepwise linear regression techniques, site index (dependent or predicted variable) was regressed against the environmental variables (independent or explanatory variables) - refer to Appendix 4. High correlations were observed amongst a number of the variables. Correlation and stepwise regression techniques were used to avoid multi-collinearity or having variables contributing overlapping information in the model. After examining standard statistics (F tests, R squared values, residual plots, examination of confidence limits and observed versus predicted plots, etc.) the following the model was chosen as the best predictor of *P. radiata* plantation site index and subsequently used to extrapolate site index to the rest of the Eden Study Area:

$SI = 16.98 + 0.87X_1 - 0.27X_2$ where :

SI = Predicted Site Index (m)

$X_1$ = Winter rainfall

$X_2$ = Annual precipitation/Potential annual evaporation.

A summary of the regression results is given in the Table 5E.

Table 5E: Multiple regression results

**Dep. Var. :** Site Index **Multiple R:** 0.64229

**F** = 196.2699 $R^2$**:** 0.41253 **df** = 2,559

**No. of cases**: 562 **adjusted** $R^2$**:** 0.41043

**p**= 0.000000

**Standard Error of Estimate :** 2.02418

**Intercept:** 16.97996 **Std. Error:** 0.41461

**t** ( 559) 40.945 **p** < 0.0000

The F test indicates that winter rainfall and the ratio of annual rainfall to annual potential evaporation are statistically significant in the prediction of site index (p < 0.001). Standard error of the estimates are useful in calculating confidence intervals for the estimates. At 2.02, the standard error of the estimate for the model is small and should ensure precise estimates of the site index.

Figure 5A is a plot of the residual versus the predicted values. The lack of an obvious pattern suggests that the model fitted was okay. Predicted values are plotted against the observed in Figure 5B.

The model accounts for approximately only 41 per cent ($r^2$ = 0.4125) of the variability in site index. Thus, as we would expect, there are other variables, in addition to rainfall and potential evaporation, that contribute information for the prediction of site index**.** In particular, it is generally known that soil factors and their interaction with other environmental variables are just as important for plant growth. In fact, their interaction is just as important. However, for reasons already explained, soil data were not used in the regression part of the analysis. Using the $r^2$ value as a measure of the strength of the relationship between the site index and the independent variables, the relationship obtained by this study can be described as moderate or average. A stronger relationship might have been obtained had:

- soil related attributes been included in the analysis and / or
- site index data been less variable within compartments.

As mentioned previously, compartment size ranged from 0.07 to 188 ha. For all compartments, irrespective of their size, one site index measure was provided. While such a measure may be representative for a small compartment, it may not be very appropriate for the larger compartments, particularly in mountainous country where steep environmental gradients may exist. This would, inevitably, weaken the relationship between site index and the independent variables in the model.

*Figure 5a: Residual versus observed values*

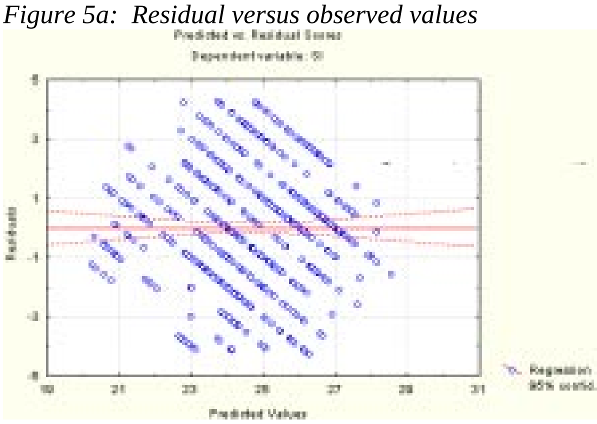
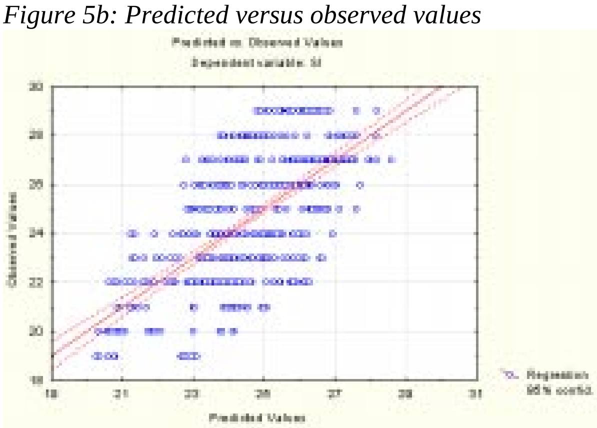


*Figure 5b: Predicted versus observed values*



Extrapolation across the study area was achieved by generating a matrix of the independent variables appearing in the final equation of the model from the corresponding spatial surfaces for the whole Eden Study Area, and then, for each unique combination of the independent variables in the matrix , using the model to predict site index. The predicted site indices were re-classed further into four broad categories as detailed further below in this section.

The statistics program also calculated the upper and lower 95 per cent confidence limits for each prediction. The use of these confidence limit is described in further below in this section.

To validate the model, the predicted site index was compared against the empirical data for an independent sample of compartments by SF staff at Bombala and Eden. Maps of predicted site index for the whole study area were generated for this purpose. Field experts from the industry (HDA, Willmott) and representatives of community based organisations (Far South Coast Total Catchment Management and SE NSW Farm Forestry Project) also provided comments on the model predictions. BRS and SF staff carried out extensive field checks to evaluate the model. For sites with no existing plantations, a site's potential capacity to support plantations of predicted site index was evaluated by visual assessment of its physical conditions, including existing native or remnant vegetation, plantings, soil physical attributes etc. In cases where plantings, e.g. woodlots or windbreaks, of known age were available, actual tree height measurements were made and projected to 20 years. This projected height was then compared with the predicted site index from the maps.

## Incorporation of soils data

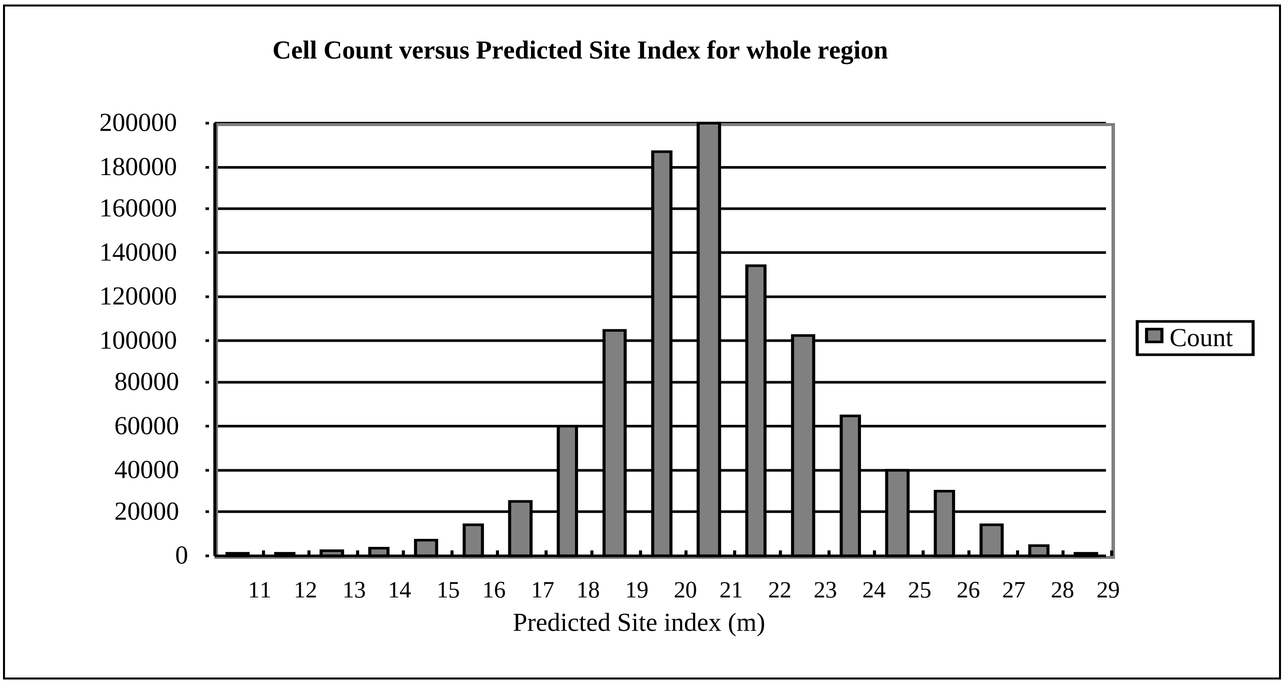
The validation process revealed the need to adjust the predicted values to account for variation in site productivity caused by differences in soil factors. For example, it was felt that given similar environmental conditions, earthy sand sites were not as productive as red basalt or granodiorite sites. Although SFNSW advised that black basalts were not as productive as red basalt given similar climatic conditions, the data available did not permit separating the two. Decision rules, involving multiplying predicted site index by a factor reflecting lithology/soil types, were developed for this exercise and listed in Table 5F.

**TABLE 5F: DECISION RULES**

| Multiplication factor | Landscape Map Unit | Lithology/Soil types |
|---|---|---|
| 0.85 | pb | sandstone, conglomerates - lithosols, stony red earths, imperfectly drained yellow podzolics |
| | me (yp) | sandstone, siltstone and conglomerates - yellow soloths, podzolics, lithosols |
| | pba | Bed rock outcrop, very shallow and stony soils |
| 0.95 | eb (mu) | sediments and meta-sediments |
| | wt | ademellite, structured red, orange and yellow podzolics |
| | mp | granodiorites/yellow podzolics |
| 1.00 | md | basalts - moderately deep and drained Kraznozems |
| | gc | granodiorites -well drained red podzolics, brown earths |
| | be, bb | granodiorites - well drained red solodic soils and earthy sands |
| | wc | granodiorite - red podzolics, brown clays and red earths |
| | mo | Ademellite with yellow podzolics and well structured soils |
| | mob | Rain forest variant of mo soil landscape. Expect stable soils with high organic matter |

After extrapolating site index to the rest of the Eden Study Area a histogram of cell count versus predicted site index was constructed, see Figure 5C.

*Figure 5c: Cell count versus predicted site index for Eden Study Area*




Using SFNSW expert knowledge and the histogram as guides, the predicted site indices across the Eden Study Area were assigned to one of the four productivity classes according to the prescriptions in Table 5G.

**TABLE 5G: PREDICTED SITE INDEX BY PRODUCTIVITY CLASS**

| Predicted site index | Productivity class |
|---|---|
| < 16 metres | Potentially uneconomic |
| 17-19 metres | Potentially low |
| 20-24 metres | Potentially medium |
| 25+ metres | Potentially high |

The descriptive productivity class attribute was subsequently incorporated into the integrated *P. radiata* plantation potential coverage.

### Modeling Results

For areas outside the exclusions (section 5.5), the predicted site index by area is summarised in Table 5H. The area figures are rounded to the nearest 100 ha.

**TABLE 5H: *P.RADIATA* MODELING RESULTS**

| Predicted Site Index (m) | Area - nearest 100 ha |
|---|---|
| equal or less than 16 | 200 |
| 17 | 1 300 |
| 18 | 4 000 |
| 19 | 18 800 |
| 20 | 58 500 |
| 21 | 60 500 |
| 22 | 32 800 |
| 23 | 15 700 |
| 24 | 3 600 |
| 25 | 1 600 |
| 26 | 1 600 |
| 27 | 100 |
| 28 | less than 100 |

As mentioned before, upper and lower 95 per cent confidence limits were determined for each predicted site index. The values of these limits determine the range of the predicted site index for each grid cell. By substituting the values of these limits for each predicted site index and for each grid cell in the study area and then applying reclassification rules listed in Table 5G, productivity class by area matrices were obtained for both the upper and lower 95 per cent confidence limits. A similar matrix was generated using the actual predicted site index. The results are compared in Table 5I. Again, the results have been rounded to the nearest 100 ha.

**TABLE 5I: POTENTIAL PRODUCTIVITY BY AREA FOR THE PREDICTED SITE INDEX AND THE 95 % CONFIDENCE LIMTS OF THE PREDICTION.**

| Productivity Class | Area (ha) Based on lower 95 % confidence limit of predicted site index | Area (ha) Based on actual predicted site index | Area (ha) Based on upper 95 % confidence limit of predicted site index |
|---|---|---|---|
| Potentially Uneconomic | 600 | 200 | less than 100 |
| Potentially Low | 49,400 | 24,000 | 10,000 |
| Potentially Medium | 145,700 | 171,100 | 184,800 |
| Potentially High | 3,000 | 3,300 | 3,800 |
| Total (corrected for rounding errors) | 198,600 | 198,600 | 198,600 |

According to Table 5I the model is predicting, with 95 per cent confidence and based on the reclassification scheme detailed above, that the area of potential high productivity lies between 3,000 and 4,000 ha. Similarly, the area of potential medium productivity lies between 146,000 and 185,000 ha.

Figure 5D shows the location of potentially capable areas outside the exclusions. The majority of the potentially high productivity areas occur around Nungatta. Large areas of potentially medium productivity occur in the Bega Valley and in a strip running from Delegate to Nimmitabel.

### 5.6.2 *E. nitens*

**Site quality data**

NPWS provided a coverage of modelled pre-European vegetation types as a raster of 100 m resolution for the Eden Study Area. The modeling of pre-European vegetation types is detailed in Keith et. al. (1995).

### Model development

The first site productivity modeling step involved identifying and masking out areas that did not meet the minimum environmental thresholds listed in Table 5J.

**TABLE 5J: MINIMUM ENVIRONMENTAL THRESHOLDS**

| Variable | Minimum value of variable | Reference |
|---|---|---|
| mean minimum temperature of coldest month | -3.5 $^0$C | Booth & Jovanovic (1991) |
| minimum total annual rainfall | 850 mm | Landsberg, Jones & Pryor (1997) & BRS (1997) |
| dry season length (consecutive months with less than 50 mm rainfall each) | 2 months | Boland,D.J. et al (1984) |

*Figure 5d: Plantation potential for* Pinus radiata

The modelled pre-European vegetation types coverage was then used to select areas that would have supported wet forests, including rainforests. The selected vegetation types are listed below (Table 5K) together with the dominant species in those vegetation types. A full list of vegetation types recognised by the pre-European vegetation types modeling is in Appendix 5

**TABLE 5K: SELECTED VEGETATION TYPES**

| Vegetation Name | Vegetation Type | Dominant species |
|---|---|---|
| Mountain Wet Layered Forest ( *E. nitens*) | 9 | *E. nitens, E. fastigata, Acacia delbata* |
| Mountain Wet Layered Forest (*E. fastigata*) | 10 | *E. fastigata* |
| Tantawangalo Wet Shrub Forest | 11 | *E. fastigata-E. cypellocarpa-E.obliqua* |
| Mountain Wet Fern Forest | 12 | *E.fastigata*, E. *cypellocarpa.* Shrubs - *Pimelea axiflora* |
| Hinterland Wet Fern Forest | 13 | *E. cypellocarpa* |
| Hinterland Wet Shrub Forest | 14 | *E. cypellocarpa, E. muellerana* |
| Mountain Wet Herb Forest | 15 | *E. cypellocarpa - E. obliqua* |
| Basalt Wet Herb Forest | 16 | *E.fastigata*, E. *cypellocarpa*. Ground cover - *Asperula scorparia* |
| Flats Wet Herb Forest | 17 | *E. viminalis* |
| Myanba Eucalypt - Fig Forest | 2 | *E. cypellocarpa, E. obliqua, Ficus rubiginosa* |
| Coastal Warm Temperate Rainforest | 6 | *Acmena smithii, Backhousia mrytifolia, Pittosporum undulatum, Ficus coronata-* |
| Cool Temperate Rainforest | 8 | *Atherosperma moshatum - Elaeocarpus holopetalus* |
| Hinterland Warm Temperate Rainforest | 7 | *Acmena smithii, Acacia melanoxylon, Pittosporum undulatum* |

If a site met the environmental conditions defined in Table 5J and was predicted by the pre-European vegetation type modeling to have supported any of the vegetation types listed in the Table 5K, it was considered to be ideally suited for *E. nitens* plantations. If a site met the above environmental conditions but its predicted pre-European forest type is not in Table 5K above, it was ranked as potentially low productivity for *E. nitens* plantation. The ideal category was further reclassed into two productivity classes based on rainfall. Areas receiving 1 000 mm or more annual rainfall were ranked as potentially high productivity while those receiving between 850 and 999 mm ranked as potentially medium productivity.

## Modeling Results

The table below summarises the results of the modeling process for areas outside of the exclusions only.

**TABLE 5L: *E.NITENS* MODELING RESULTS**

| Productivity Ranking | Area - nearest 100 ha |
|---|---|
| Low | 61 000 |
| Medium | 5 200 |
| High | 600 |

Figure 5E shows the location of the areas capable of growing *E. nitens*. Again, the areas shown in this map are those outside of the exclusions. Large areas of potentially low productivity exist north of Bega and also around Nungatta. Areas of potentially high productivity are small and fragmented. The largest potentially high productivity patches are found near Mount Darragh. Contiguous areas of potentially medium productivity occur south east of Nimmitabel on Brown Mountain and around Cathcart.

*Figure 5e: Plantation potential for* Eucalyptus nitens

# 6. LAND SUITABILITY

## 6.1 THE CONCEPT OF LAND SUITABILITY

Land suitability studies usually take into consideration both biophysical factors (capability factors) as well as socioeconomic factors, which will affect the ability of land to support a particular use, such as plantations. In accord with the usual definition, lands that are biophysically capable of supporting plantations (as per section 5) have been considered for socioeconomic plantation suitability in this study.

Economic factors that could be considered include the price of land, local government zonation, distance from roading and processing infrastructure, and environmental costs. There may also be some social considerations and costs associated with plantation establishment, (SPIS, 1990). There are a number of variables that contribute to the suitability of land for plantation establishment:

- Cost of land per unit area
- Methods of purchase (lease, purchase of unimproved land, purchase of land and improvements)
- Proportions of land available for planting
- Distance to processor
- Availability of appropriate processor(s)
- Parcel size (logistically, larger is better due to economy of scale)
- Road access
- Local council zoning
- Proximity to other zonings
- Opportunity cost (e.g. agriculture)
- Returns from plantation products
- Availability of markets
- Price of land in adjacent Eden Study Areas
- Environmental costs

Perhaps the largest single consideration in determining the suitability of land, from the plantation developer’s perspective, is its price. Land that is physically capable of growing agricultural crops (such as cereals or fruit), may be unsuitable for afforestation, due to the higher rate of return from the agricultural crops. Land that can support such agricultural cropping is usually relatively valuable. In addition, land that is situated on the outskirts of urban areas, or along arterial road corridors may be in demand for housing sub-division, or small rural holdings, also making it relatively valuable, precluding its use for plantation forestry. Such properties may also be too small to support viable plantations. In the past, plantation areas have generally needed to be larger than 5 ha for efficiency of scale in harvesting. However, with the rise in popularity of agroforestry systems, this situation is likely to change in the future, especially in relation to specialty or niche market timbers which may alter conventional price structures for harvesting

## 6.2 LAND VALUES

A preliminary analysis of private land sales records was undertaken. These data included sales from local real estate agents within the Eden Study Area and records from the Bega Shire Council. Due to very low number of sales of larger properties within the last 5 years, no quantitative conclusions could be made on the spatial arrangement of land values using available sales data.

However, from communications with local residents and real estate agents the following land uses were ranked according to their indicative un-improved land values. A land use dataset was therefore required to enable plantation suitability assessments to be undertaken.

**TABLE 6A: RANKED LAND USES**

| Land use | Rank |
|---|---|
| Rural residential* | 6 |
| Dairying | 5 |
| Mixed grazing (dairying/coastal grazing) | 4 |
| Coastal grazing | 3 |
| Foothill grazing (tablelands) | 2 |
| Tablelands grazing (tablelands) | 1 |

* residential areas were excluded from analysis

## 6.3 PROPORTIONS OF LAND AVAILABLE FOR PLANTATION ESTABLISHMENT

Even though a large area of land may be capable and economically viable to purchase for commercial plantations, it is unrealistic to expect all the current owners of this land to be willing to sell or to convert their entire holdings into plantations.

Land could be available for plantation purposes in two ways, either through some form of joint venture arrangement between the landholder and investor or through outright purchase by investors. With the joint venture arrangement, it is envisaged that a landholder would avail only a portion of their land for plantation establishment. This proportion would depend on the landholder's perception of the following:

- return from joint venture in comparison to return from existing or alternative land use;
- philosophical attitude towards plantations,
- limitations in flexibility a tree based land use implies,
- level of reliance on income from farming activities,
- on-farm benefits over and above the wood value of trees such as mitigation against land degradation agents, shade and shelter for stock (Landsberg et. al. 1990).

It is not unreasonable to expect that some land use categories could avail a greater proportion of land to plantation establishment than others. For example, today's dairy market is stronger than the beef, lamb and wool markets[4]. Consequently, less land, in proportion terms, would be expected to be made available for plantation establishment from this land use category than from other land uses.

The alternative, purchasing land for plantation establishment, would also be strongly influenced by land use. Because current returns from dairy farming ($ ha$^{-1}$yr$^{-1}$) are higher than those from other land uses, purchase prices for such farms would be expected to be higher. Dairy farms, by necessity, generally have more farm improvements in comparison to other land uses, further adding to the overall land value. A BRS study of property values in the Central Highlands (Victoria) CRA Plantation Potential Analysis (1997) project established that both property size and distance from major population centres were negatively correlated with property or land value per unit area. Part of the reason for this is the value and amount of land improvements, e.g. buildings, associated with small land parcels. Land on the fringes of population centres has potential for residential subdivision, making it more valuable.

Local government zoning may also have a significant impact on the capacity to establish plantations. In the case of the

[4] Pers. comm. - Garret Barry, Bega Valley Shire Council (BVSC) Town Planner, 18 July 1997.

Residential Use category of shire/council plans, local government zoning regulations restrict plantations establishment. Moreover, land values of these areas would be quite high, making purchase of land for plantation establishment a less profitable venture. These areas, together with all public land, were excluded from further analysis.

## 6.4 AVAILABLE DATA

The following datasets relating to plantation suitability were available for this study:

- land tenure - 1:25 000 scale dataset delineating eight public land categories and one private land category;
- land sales records - five years of property sales records from local real estate agents and Bega Valley Shire Council (BVSC);
- shire/parish boundaries - 1:25 000 scale provided by BVSC;
- environmental plans - 1:25 000 scale dataset delineating local landuse zoning within the Bega, Brogo and Towamba valleys;
- road networks - 1:250 000 scale on private land provided by AUSLIG;
- processing facilities - Bombala and Eden Mills;
- satellite imagery - Landsat Thematic Mapper data for December, 1995; and
- slope - derived from 25 metre DEM provided by LIC.

### 6.4.1 Derivation of a land use dataset

A number of the above datasets were used to create a land use layer for the Eden Study Area, as follows:

- Land tenure was used to provide a mask of public and private lands;
- Environmental plans were used to delineate rural residential areas within the Bega, Brogo and Towamba valleys;
- Satellite imagery was used to delineate urban areas and, through consultation with BVSC and Bombala Shire Council, the landuse categories described in Section 6.2 were mapped and validated at approximately 1:100 000 scale.

Table 6B compares the areas for each land use category and Figure 6A shows the location of each land use category within the Eden Study Area. When comparing figures from Table 6B with any other figures, the boundaries of the areas to which they pertain should be noted. The figures in Table 6B include areas outside the Eden CRA boundary for each land use.

**TABLE 6B : LAND USE BY AREA**

| Land Use | Forested Area (ha) | Non-Forested Area (ha) | Total Area (ha) |
|---|---|---|---|
| Coastal Grazing | 11 600 | 34 800 | 46 400 |
| Dairying | 13 200 | 35 400 | 48 600 |
| Foothills Grazing | 19 900 | 38 100 | 58 000 |
| Mixed Grazing | 72 300 | 35 300 | 107 600 |
| Tablelands Grazing | 43 300 | 92 700 | 136 000 |
| Rural Residential | 12 300 | 12 400 | 24 700 |
| Public Land | 434 400 | 50 000 | 484 400 |
| Total | 607 000 | 298 700 | 905 700 |

### 6.4.2 Slope classes

A coverage of two slope classes, less than 18 degrees and equal to or greater than 18 degrees, was built based on the 25 metre resolution digital elevation model (DEM) of the Eden Study Area. The 18 degree threshold concurs with requirements to satisfy the *Soil Conservation Act* (Mike Welch, SFNSW Albury - pers.comm.). Also, these classes provide the basis for allocating harvesting costs within potentially suitable areas.

*Figure 6a: Land tender and land use*

# 7. DATA INTEGRATION

This section integrates the results of the capability and suitability components of the project. The results of this integration are matrices with the following attributes:

- land use;
- slope class;
- productivity class or site index and
- area (ha).

First, coverages of the unsuitable areas, in terms of land use, were generated for each species. This was achieved by combining all public land, residential areas, forested land and areas within road and/or stream buffers with areas that did not meet the environmental thresholds for each species as explored in Chapter 5. These combined areas were excluded from further analysis.

To conform with the definition of Land Suitability presented in Chapter 6, it should be noted that all areas that are capable of supporting plantations and are outside exclusions are referred to as '"Potentially Suitable" for plantations in this chapter. This is because the results of the economic analysis have not been incorporated at this stage. The results of the economic analysis are presented and discussed in Chapter 8.

## 7.1 *PINUS RADIATA*

The results of the integration process indicate that there is approximately 198 000 ha of cleared private land in the Eden Study Area that are potentially suitable of growing *P. radiata* plantations. The land use proportions of this land are given in the Table 7A. Most of the potentially suitable land is in the Tablelands Grazing land use category (38%). The other land uses have roughly similar proportions, averaging at about 15 per cent of the total. The same table also summarises land use by potential productivity. The majority of the potentially highly productive areas occur in the Foothills Grazing land use category. Negligible amounts of potentially highly productive areas exist in Dairying and Coastal grazing categories.

**TABLE 7A: LAND USE BY POTENTIAL PRODUCTIVITY - *P. RADIATA.***

| Land Use | Low Potential Productivity Area (ha) | Medium Potential Productivity Area (ha) | High Potential Productivity Area (ha) | Total Potentially Suitable Area (ha) | Proportion of Total Area (%) |
|---|---|---|---|---|---|
| Coastal Grazing | 2,000 | 28,000 | | 30,000 | 15% |
| Foothills Grazing | 3,000 | 26,000 | 3,000 | 32,000 | 16% |
| Tablelands Grazing | 15,000 | 61,000 | less than 200 | 76,000 | 38% |
| Mixed Grazing | 3,000 | 27,000 | less than 100 | 30,000 | 15% |
| Dairying | 1,000 | 29,000 | | 30,000 | 15% |
| Total - All Uses | 24,000 | 171,000 | 3,000 | 198,000 | 100% |

Approximately 2 per cent of the cleared and potentially suitable land is predicted to have a high potential productivity under *P. radiata* plantations and more than 86 per cent is predicted to have medium productivity. Across all three productivity classes, the proportion of land of slope equal to or greater than 18 degrees is relatively small. Table 7B gives the area proportions by potential productivity and compares areas in different slope class for each productivity class.

**TABLE 7B: POTENTIAL PRODUCTIVITY BY SLOPE CLASS - *P. RADIATA*.**

| Potential Productivity | Potentially Suitable area on low slope (< 18$^{o}$) | Potentially Suitable area on high slope (>= 18$^{o}$) | Total Potentially Suitable Area (ha) | Proportion of Total (%) |
|---|---|---|---|---|
| Low | 23,000 | 1,000 | 24,000 | 12% |
| Medium | 169,000 | 2,000 | 171,000 | 86% |
| High | 3,000 | | 3,000 | 2% |
| Total | 195,000 | 3,000 | 198,000 | 100% |

## 7.2 EUCALYPTUS NITENS

The modeling results indicate that there is approximately 67,000 ha of cleared private land in the Eden Study Area potentially suitable for *E. nitens* plantations. The land use proportions of this land are given in the Table 7C. Most of the potentially suitable land, albeit low potential productivity, occurs in the dairying category with 37 per cent of the total. The Coastal Grazing land use category has the least amount at 7 per cent of the total. The other three land use categories' proportions range from 14 per cent to 25 per cent of the total. The same table also summarises land use by potential productivity. All land uses are characterised by large areas of potentially low productivity in comparison to the other productivity classes.

**TABLE 7C: LAND USE BY POTENTIAL PRODUCTIVITY - *E. NITENS.***

| Land Use | Low Productivity Area (ha) | Medium Productivity Area (ha) | High Productivity Area (ha) | Total Potentially Suitable Area (ha) | Proportion of Total Area (%) |
|---|---|---|---|---|---|
| Coastal Grazing | 3,900 | 500 | less than 100 | 4,400 | 7% |
| Foothills Grazing | 10,000 | 1,500 | 300 | 11,800 | 18% |
| Tablelands Grazing | 7,700 | 1,500 | less than 100 | 9,200 | 14% |
| Mixed Grazing | 15,400 | 1,200 | 100 | 16,700 | 25% |
| Dairying | 24,000 | 500 | 200 | 24,700 | 37% |
| Total - All Uses | 61,000 | 5,200 | 600 | 66,800 | 100% |

Less than 1 per cent, approximately, of the cleared private land and potentially suitable land is predicted to have a high potential productivity under *E. nitens* plantations and more than 91 per cent is predicted to have low productivity. Across all three productivity classes, the proportion of land of slope equal to or greater than 18 degrees is relatively small. Table 7D gives the area proportions by potential productivity and compares areas in different slope class for each productivity class.

**TABLE 7D: POTENTIAL PRODUCTIVITY BY SLOPE CLASS - *E. NITENS.***

| Potential Productivity | Potentially Suitable area on low slope (< $18^o$) | Potentially Suitable area on high slope (>= $18^o$) | Total Potentially Suitable Area (ha) | Proportion of Total (%) |
|---|---|---|---|---|
| Low | 59,000 | 2,000 | 61,000 | 91% |
| Medium | 5,000 | 200 | 5,200 | 8% |
| High | 600 | | 600 | 1% |
| Total | 64,600 | 2,200 | 66,800 | 100% |

## 7.3 COMPARISON OF RESULTS WITH OTHER STUDIES

In chapter 4 of this report, reference was made to previous studies that looked at plantation potential in the Eden Study Area. The general approach taken by these studies has also been provided. Given that the boundaries of these studies do not overlap in many areas, direct comparison of results from these studies would be misleading. However, it is still useful to determine the order of magnitude of differences between the predictions. The predicted potentially suitable areas for each report are provided in Table 7E.

For hardwood, *E. nitens*, the results of this study are of the same order of magnitude as the Lansberg *et. al* (1990) and Stanton (1990) studies. While Jurskis's prediction of area potentially suitable for growing hardwood plantations is significantly lower than that provided by other studies, it is comparable to the sum of the potentially medium and high productivity categories of this study (9 000 vs. 5 800 ha). Stanton's study predicts only 1 100 ha to be ideal for hardwood plantations in the Eden Study Area out of the 59 400 ha predicted suitable.

Only one other study, apart from this one, (Jurskis, 1996) provides an estimate of potentially suitable area for growing softwood plantations (*P. radiata*). Given the scale of the studies, the estimates may be described as comparable. However, it should be noted that the Jurskis estimate includes 75 000 hectares of area rated 'potentially suitable for pine' in the rainfall zone 600-700 mm. This study excludes areas receiving less than 650 mm annual rainfall.

## TABLE 7E: COMPARISON OF RESULTS FROM VARIOUS PLANTATION POTENTIAL STUDIES

| Study*<br><br>(*Note that the study boundaries of these studies do not match) | *P. radiata*<br><br>Predicted potentially suitable area (ha) | Hardwood<br><br>Predicted potentially suitable area (ha) |
|---|---|---|
| Jurskis (1996) | 220 000 | 9 000 |
| Landsberg et. al. (1990) | Not applicable | 70 000 |
| Stanton (1990) | Not applicable | 59 400 |
| Booth and Jovanovic (1991) | Not applicable | 120 300 |
| BRS 1998 | 198 000 | 66 800 |

# 8. ECONOMIC ANALYSIS

## 8.1 AIM

The purpose of this analysis is to assess the economic potential for plantation establishment in the Eden Regional Forest Agreement (RFA) region of New South Wales. According to economic principles, land use should be determined by selecting those activities that maximise the value of the land. This study compares the estimated value of land currently under agricultural use with the potential land value from selected plantation developments. Environmental and aesthetic costs and benefits associated with plantation development in the region are not included in the analysis.

The aim of the analysis is not to suggest what level of plantation development should occur within the region, rather, to provide an indication of the area and location of land in the region where the potential land value from plantation development exceeds the estimated land value. The eventual level of plantation development within the region will depend on the full range of costs and benefits borne by the private investor, which may include not only the financial returns from plantation activities, but may also include other factors such as the influence of government regulations and environmental considerations.

## 8.2 METHOD

A discounted cashflow approach, incorporating a residual pricing method, is used to determine the land values associated with the development of plantation forests in the region. This method calculates the stumpage price of plantation timber harvested by subtracting all costs involved with converting the plantation resource to final products (including harvesting, transportation and processing) from the market revenue for the products. The net present value (NPV) of any single plantation rotation is determined by subtracting all discounted costs associated with establishing and maintaining the plantation from the discounted revenues associated with the sale of the plantation timber. This rotation is repeated in perpetuity to calculate the NPV associated with using this land for plantations. For each plantation regime, the optimal choice of rotation length is determined as the period for which the NPV is highest. By comparing the NPV for the optimal plantation regime against the value of land estimated by landholders, an indication of the competitiveness of plantations as a land use within the region can be determined. This method has been used in a number of other studies to determine the competitiveness of plantation development, see for example Stephens, Hansard and Dean (1993) and Sedjo (1983).

### 8.2.1 Data and Assumptions

There are a number of simplifying assumptions used in the analysis, including the following:

- Three plantation regimes are used in the region: a *Pinus radiata* sawlog regime, a *P. radiata* pulplog regime, and a *Eucalyptus nitens* pulplog regime. A *E.nitens* sawlog regime is not considered as there is no verifiable sawlog yield and market price information for hardwood plantation timber.

- Four forest products are produced from plantations in the region: sawn timber, plywood, and Medium Density Fibreboard (MDF), all from *P. radiata*, and wood chips derived from *E. nitens*;
- The processing mills used in the analysis and their cost and output characteristics are assumed to be continually repeated once they reach shutdown age;
- All plantation investments incur the same costs. In reality these costs vary for each individual plantation depending on size of investment, type of investor, individual site conditions, existing roading etc;
- All products except for sawn timber are exported to international markets;
- Eden is a small supplying region both for Australia and the rest of the world, such that forest product prices are determined elsewhere independently of volumes produced in the Eden region;
- Real prices for forest products and returns to existing agricultural land uses in the region are based on 1997 levels and are assumed to be constant forever; and
- A real discount rate of 7 per cent is used for all calculations.

The structure of the plantation based processing industry within the region is based upon an assessment of processing development options by Margules Pöyry 1997. The industry structure used in the study includes:

- 2 softwood sawmills located at Bombala (combined capacity of around 700 000 cubic metres per year);
- 2 MDF mills based on softwood fibre at Bombala ( combined capacity of around 400 000 cubic metres per year);
- a softwood plywood mill, located at Bombala (capacity of 120 000 cubic metres per year); and
- a chip mill exporting hardwood chips at Eden (capacity of around 500 000 cubic metres per year).

The current industry in the Eden RFA region principally consists of sawmilling operations, with an intake of about 75 000 $m^3$ per year, and an export woodchipping operation, with a wood intake of about 480 000 $m^3$ per year. Thus, the scale of this existing industry is much less than the capacity of the potential industry discussed above. To achieve the returns and scale of production derived in this analysis a significant magnitude of investment is required.

Transport costs from each mill to both domestic and international markets, and details of timber processing activities, including the capacity of each mill, recovery rates, and fixed, variable, and capital costs are based on Margules Pöyry 1997. This information was used to calculate, for each mill, the mill door delivered price of logs from plantation areas.

Information on the biophysical potential for plantations was provided by the Bureau of Resource Sciences (BRS) and State Forests of NSW. Land in the region was separated into four productivity classes - high, medium, low, and unsuitable, for each plantation species (see Chapter 5).The upper and lower 95 per cent confidence limits of the area of each productivity class were also calculated. Public, private forested and residential land as well as land within a certain distance from major roads and streams (see Chapters 5 & 6 for details) were excluded from the economic analysis.

Estimates of the volumes of sawlogs and pulplogs from thinning and clearfall operations for each of the regimes and for each productivity class were derived from yield tables provided by State Forests of NSW. The yield tables are provided in Appendix 7. Altogether, three yield tables were provided, two of which were for *P. radiata* and the one for *E. nitens*. One *P.radiata* yield table was based on a management regime geared to produce mainly sawlogs (*Pinus radiata* Sawlog Regime) and the other was based on a regime focusing on pulplogs (*Pinus radiata* Pulplog Regime). The *E. nitens* yield table assumed that equal volumes of sawlogs and pulp logs would be produced, however, for reasons alluded to earlier, the economic analysis section assumed that all produce from this regime would be sold as pulplogs. Hence, the *E. nitens* regime has been termed *E. nitens* Pulplog Regime.

For each yield table, volume yields by product (sawlog and pulpwood) could come from either a thinning or a clearfelling operation. Where a number of clearfell options were provided in the yield table, the one yielding the highest returns was chosen. The timing of the operation is dependent mainly upon: the products for which the plantation is being managed, site productivity, and economic considerations. The three productivity classes considered in the yield tables are related to productivity classes identified by site index modeling discussed in Chapter 5. Also provided in the yield tables are age of stand and corresponding growth related information (basal area, mean annual increment (MAI)) as well as stocking levels. The Forestry-oriented Linear Programming Interpreter (FOLPI) (FRI, 1991) was used to model the harvest volumes.

The main agricultural and grazing activities in the region include tablelands grazing, coastal grazing and dairying. Land values were estimated from ABARE's AAGIS (Australian agricultural and grazing industries survey) and ADIS (Australian dairy industry survey) farm survey data. These land values are derived from landholder's estimates of the value of their land. It was not possible to further disaggregate these activities by land productivity measures. Estimates of the agricultural and grazing land values for the region are mapped in figure 8k using the landuse data described in chapter 6.

Using the estimated cost and revenue data by regime and productivity class (see Appendix 6), the land value (per hectare) of each regime for each land productivity class and transport zone were calculated. These are compared with land values estimated by the land owners in the region.

The transport zones were determined by subdividing the region into 10 km by 10 km grid squares. In order to determine transport costs from the plantations to processing plants, the minimum cost path from each square to the processing centres was determined using information on known sealed and unsealed roads.

### 8.2.2 Sensitivity analysis on key parameters

To take account of the variability surrounding forest product prices and yields associated with plantation development, five scenarios are presented for the net present value calculations. These include:

a) a baseline price for forest product prices and predicted productivity by area matrix for *P. radiata* plantations (baseline scenario);

b) a price that is 10 percentage points higher than the baseline forest product price and predicted productivity by area matrix (high price scenario);

c) a price that is 10 percentage points lower than the baseline forest product price and predicted productivity by area matrix (low price scenario);

d) a baseline price and area by productivity matrix determined by reclassifying the upper 95 per cent confidence limit of the site index (see table 5i) for *P. radiata* plantations (upper level productivity scenario); and

e) a baseline price and area by productivity matrix determined by reclassifying the lower 95 per cent confidence limit of the site index for *P. radiata* plantations (lower level productivity scenario).

## 8.3 RESULTS

Simulation results for the baseline, high price, low price, upper level productivity and lower level productivity scenarios are provided for plantation values by land area (tables 8a,8b, figures 8a,c,e,g,i), and for potential plantation development by existing land use category and plantation management regime (figures 8b,d,f,h,j).

Changes in any of the assumed conditions discussed previously will influence the potential for plantation investment. An example of this is establishment costs which constitute a large proportion of early investment costs. Changes in establishment or management costs have a large influence on estimated net present values.

**TABLE 8A: AREA (ROUNDED TO NEAREST 100 HECTARES) WHERE PLANTATION VALUES EXCEED EXISTING ESTIMATED VALUES**

| | | | | | scenario | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **P. radiata scenarios** | *predicted site index area (ha)* | *upper 95% confidence limit of site index area (ha)* | *lower 95% confidence limit of site index area (ha)* | Baseline (a) | High price (b) | Low price (c) | Upper level productivity (d) | Lower level productivity (e) |
| | High | *3,300* | *3,800* | *3,000* | 3,300 | 3,300 | 2,300 | 3,800 | 3,000 |
| Productivity | Medium | *171,100* | *184,800* | *145,700* | 142,100 | 171,100 | 79,400 | 154,400 | 123,300 |
| | Low | *24,000* | *10,000* | *49,400* | 17,800 | 22,700 | 0 | 8,400 | 27,700 |
| | **Total** | ***198,400*** | ***198,600*** | ***198,100*** | **163, 200** | **197,100** | **81,700** | **166,600** | **154,000** |
| | | | | | scenario | | | | |
| | **E. nitens** | *predicted site index area (ha)* | *upper 95% confidence limit of site index area (ha)* | *lower 95% confidence limit of site index area (ha)* | Baseline (a) | High price (b) | Low price (c) | Upper level productivity (d) | Lower level productivity (e) |
| | High | *600* | *na* | *na* | 400 | 600 | 400 | na | na |
| Productivity | Medium | *5,200* | *na* | *na* | 3,100 | 4,700 | 6 | na | na |
| | Low | *61,000* | *na* | *na* | 0 | 9,100 | 0 | na | na |
| | **Total** | ***66,800*** | ***na*** | ***na*** | **3,500** | **14, 400** | **400** | **na** | **na** |

### 8.3.1 Baseline scenario

The land value from plantation development is greater than the estimated land value from existing agricultural uses for about 82 per cent, or 163 000 hectares, of the suitable land area in the region. The radiata sawlog regime generates the highest value for about 66 per cent of this area, while the radiata pulplog regime generates the highest value for the remainder of the area. The area of low, medium, and high productivity land, as determined by site index modeling, is 24 000, 171 100, and 3300 hectares respectively (see table 8a).

Although the *E.nitens* pulplog regime does not generate the highest plantation land values for much of the area studied, the values are nonetheless greater than existing estimated land values on approximately 3500 hectares of the area.

The majority of grazing land in the region generates a potential value from plantations that is higher than the current estimated value (see Figure 8l). The radiata sawlog plantation regime produces the highest value on tablelands grazing areas, while the radiata pulplog regime generates the highest value on the foothills grazing areas. Dairying has higher values than plantations on most existing dairying land, with only a negligible amount (less than 10 hectares) of this land providing a higher value for *E. nitens* plantations than for dairy.

*Figure 8a: Potential plantation area by current land use.*

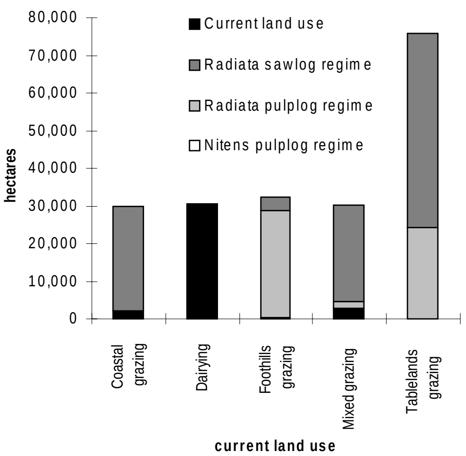
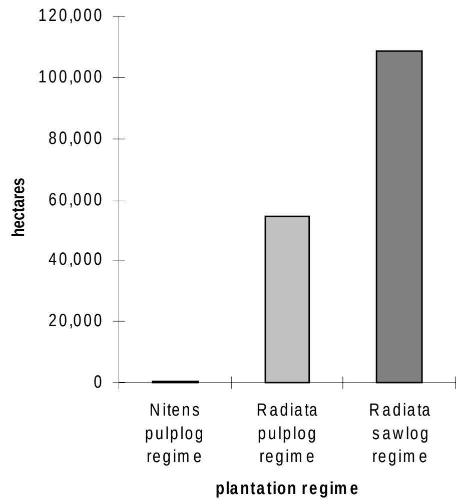



*Figure 8b: Potential plantation area by regime*




### 8.3.2 High price scenario

Under the high price scenario (see table 8a), the area of land where plantation returns are greater than the value of existing agricultural activities increases to about 197 000 hectares, or about 99 per cent of total suitable land in the region. About 88 per cent of the total land area provides a land value above $5400 per hectare for plantation development (refer to figure 8m). The area of existing dairy land that generates a higher value from dairying than from plantations, falls from approximately 100 per cent in the baseline scenario to only 4.5 per cent in the high price scenario.

As with the previous scenario, the *E. nitens* regime does not generate the highest plantation land values, although these values are greater than the existing estimated land values on approximately 14,000 hectares of suitable land.

*Figure 8c: Potential Plantation area by current land use: high price scenario.*

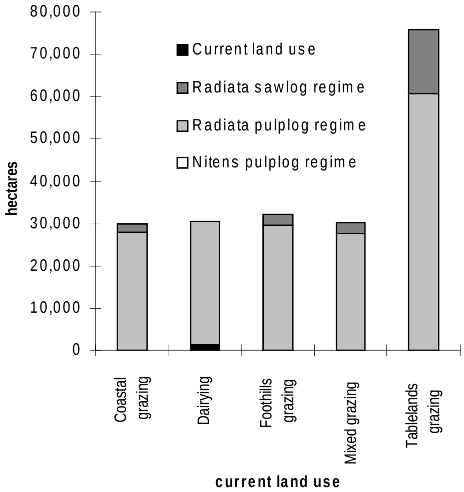
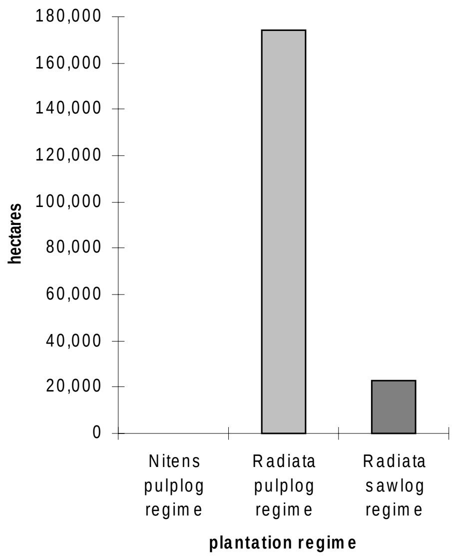



*Figure 8d: Potential plantation area by regime: high price scenario.*




### 8.3.3 Low price scenario

Under the low price scenario, the potential value of plantations declines sharply. The area of land where plantation land values exceed the existing estimated values falls to 41 per cent of the total land area, or to about 82 000 from 163 000 hectares. All but 440 hectares of the land area has returns of less than $1800 per hectare for plantations (see Figure 8n). The radiata pulplog regime was found to be sensitive to price changes, with the potential area for radiata pulplog regimes ranging from 88 per cent under the high price scenario, to 2.7 per cent under the low price scenario.

Under this scenario, only on about 400 hectares of the total area analysed, are the values generated by the *E. nitens* pulplog regime greater than existing estimated land values.

*Figure 8e: Potential Plantation area by current land use: low price scenario.*

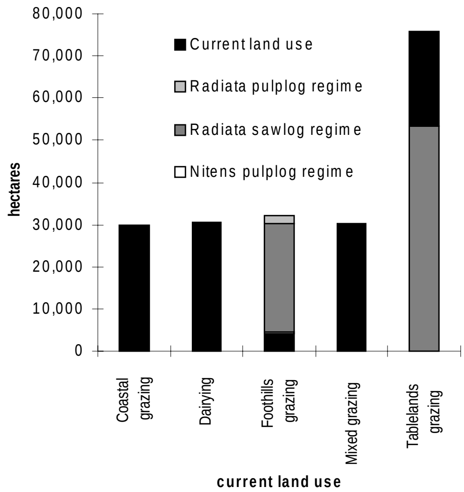
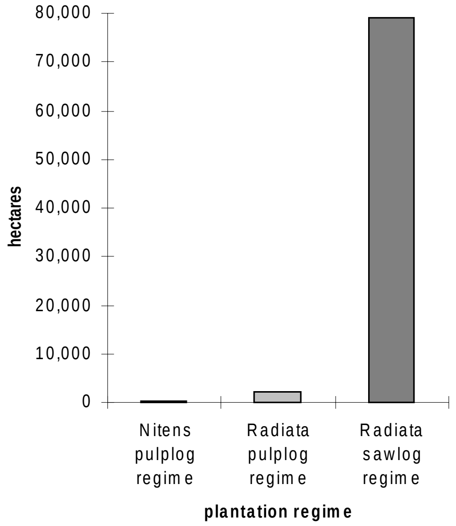


*Figure 8f: Potential plantation area by regime: low price scenario.*




### 8.3.4 Upper level productivity scenario

Under the upper level productivity scenario, the area of land where plantation values are greater than the existing estimated values increases only slightly above the baseline of 163 000 to 166 600 hectares, or 84 per cent of the available land in the region. About 71 per cent of the total land area provides returns to plantations between $2701 and $3600 per hectare, while a further 23 per cent of the land area provides returns in excess of $3600 per hectare.

*Figure 8g: Potential plantation area by current land use: upper level productivity scenario.*

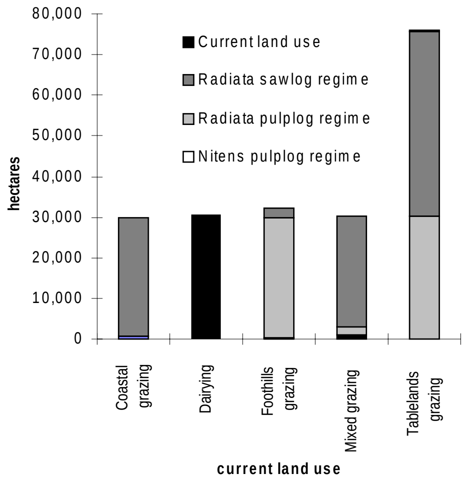
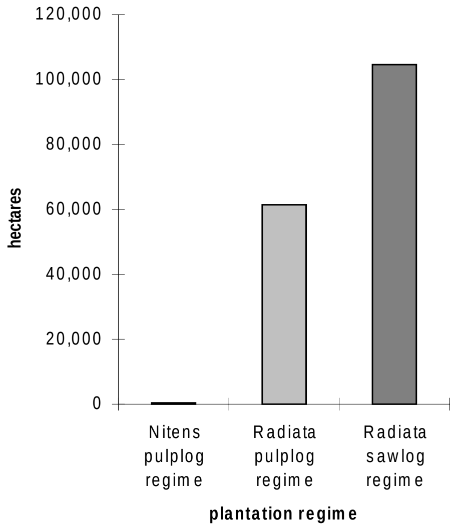



*Figure 8h: Potential plantation area by regime: upper level productivity scenario.*




### 8.3.5 Lower level productivity scenario

Under the lower level productivity scenario the value from plantations declines, with 82 per cent of the total land area providing a potential value to plantations of less than $3600 per hectare. The area of land that provides plantation values which exceed the current estimated value is reduced from 163 000 to about 154 000 hectares.

*Figure 8i: Potential plantation area by current land use.*

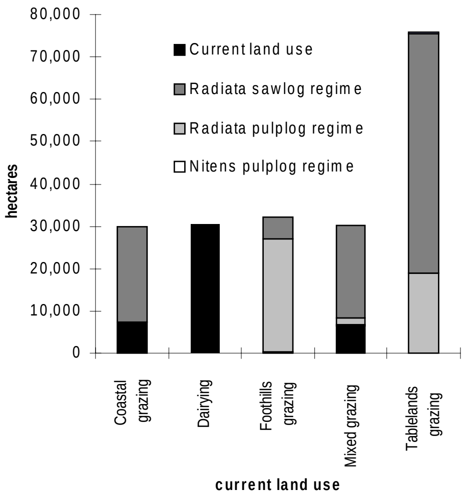
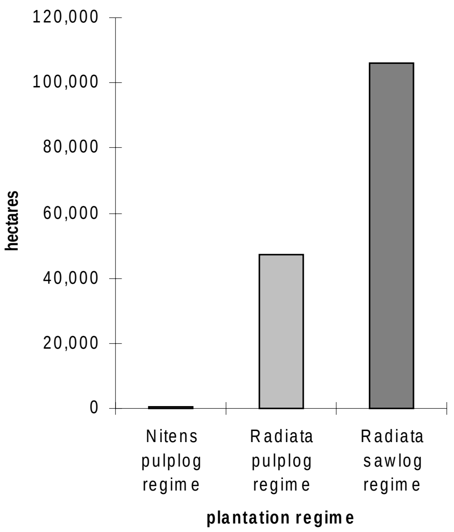



*Figure 8j: Potential Plantation area by regime: lower level productivity scenario.*




Using these upper and lower 95 per cent confidence limits provides an understanding of the influences data errors in the statistical modeling of site index may have in the calculated area of each productivity class, and hence the implications for land potentially economic for plantation development. The relationship between potential land values for the three plantation regimes changes only slightly between the baseline and upper and lower level productivity scenarios. The main change is the amount of land that falls into each productivity category as shown in table 8a.

### 8.3.6 Wood yields

Table 8d provides estimates of the wood yields assuming 10 per cent of the land area found suitable (table 8a) for plantations in this study is developed into the highest net present value regime. These potential wood yields assume that there is an even age structure of plantations across all plantation regimes and land productivity classes, and that all associated establishment, processing and marketing infrastructure is developed and of sufficient capacity. As a result, these yields are likely to provide an over-estimate of the actual wood yields associated with plantation development in the region.

Under these assumptions, the baseline scenario results in a wood flow of 210 000 $m^3$ of sawlogs and 61 000 $m^3$ of pulplogs from the region per year. Under the high price scenario, and in comparison with the baseline scenario, sawlog yields increase by 7.4 per cent and pulplog yields by 85 per cent. Within this scenario, yields from the radiata sawlog regime are seen to fall as radiata pulpwood absorb a large proportion of potential land area. For the low price scenario, sawlog yield falls by 45 per cent and pulplog yield falls by 66 per cent. The upper level productivity scenario results in the sawlog yield increasing by 3.5 per cent and pulplog yield increasing by 2.9 per cent, while the lower level productivity scenario results in a reduction of sawlog and pulplog yield by 7.5 per cent and 5.2 per cent respectively.

On an economic basis, *E.nitens* is not the preferred plantation species. Even with this being the case, existing markets or investor preferences may determine that hardwood plantations are nevertheless established. Table 8b outlines the potential wood flows associated with a 10 per cent development of land where hardwood plantations have a greater net present value than existing agriculture.

**TABLE 8B: EDEN REGION-PLANTATION WOOD FLOWS (PULPWOOD) FROM A HARDWOOD SCENARIO ASSUMING 10 PERCENT OF POTENTIAL PLANTATION AREA DEVELOPED**

| scenario | baseline | high price | low price |
|---|---|---|---|
| volume ($m^3$/year) | 7,413 | 17,281 | 1,253 |
| area base (ha) | 350 | 1,400 | 40 |

## 8.4 EMPLOYMENT

According to Clark (1995) about one person is employed in plantation management (including replanting harvested plantations) for every 1000 hectares of plantation established. Additionally about one person is employed in plantation wood harvesting and cartage to mills for every 7000 $m^3$/year of plantation timber harvested.

Using a baseline scenario as outlined in section 8.3.6 and the figures provided by Clark (1995). The employment effects would therefore be about 16 new jobs in establishment and management plus long term employment in harvesting and cartage of 39 jobs.

## TABLE 8C: EDEN PLANTATION REGION- PLANTATION RETURNS AND POTENTIAL LAND AREA

| Plantation return $/ha | Baseline scenario ha | High price scenario ha | Low price scenario ha | Upper level productivity scenario ha | Lower level productivity scenario ha |
|---|---|---|---|---|---|
| $0-900 | 1,050 | 148 | 57,352 | 5,025 | 160 |
| $901-1800 | 23,066 | 12 | 140,832 | 44,831 | 9,898 |
| $1801-2700 | 2,639 | 768 | 421 | 1,930 | 2,734 |
| $2701-3600 | 132,084 | 23,231 | 12 | 111,756 | 140,566 |
| $3601-4500 | 37,499 | 0 | 7 | 32,993 | 42,631 |
| $4501-5400 | 2,286 | 49 | | 2,089 | 2,635 |
| $5401-6300 | | 78,184 | | | |
| $6301-7200 | | 92,921 | | | |
| $7201-8100 | | 1,029 | | | |
| $8101-9000 | | 2,282 | | | |
| **Total** | **198,624** | **198,624** | **198,624** | **198,624** | **198,624** |

## TABLE 8D: EDEN REGION - ANNUAL PLANTATION WOOD FLOWS FROM VARIOUS SCENARIOS ASSUMING 10 PER CENT OF POTENTIAL PLANTATION AREA DEVELOPED

| | Wood flows | | Woodflows under varying scenarios ($m^3$/year) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Plantation regime | Baseline scenario | | High price scenario | | Low price scenario | | Upper level productivity scenario | | Lower level productivity scenario | |
| | Saw m3 | Pulp m3 | Saw m3 | Pulp m3 | Saw m3 | Pulp m3 | Saw m3 | Pulp m3 | Saw m3 | Pulp m3 |
| Radiata sawlog | 146,173 | 26,969 | 22,160 | 8,412 | 112,524 | 17,794 | 145,164 | 24,766 | 138,704 | 27,937 |
| Radiata pulplog | 64,152 | 32,439 | 203,657 | 103,432 | 3,060 | 1,421 | 72,530 | 36,669 | 55,857 | 28,238 |
| Nitens pulplog | | 1,190 | | 244 | | 1,242 | | 891 | | 1,244 |
| **Total** | 210,326 | 60,598 | 225,817 | 112,088 | 115,584 | 20, 457 | 214, 694 | 62,326 | 194,561 | 57,419 |

*Figure 8k: Estimated net present value of agriculture ($per hectare) on land potentially suitable for plantations*

*Figure 8l: Estimated net present value of plantations ($ per hectare) on potentially suitable land (Baseline Scenario)*

*Figure 8m: Estimated net present value of plantations ($ per hectare) on potentially suitable land (High Price Scenario)*

*Figure 8n: Estimated net present value of plantations ($ per hectare) on potentially suitable land (Low Price Scenario)*

## 8.5 CONCLUDING COMMENTS

This analysis indicates that there are significant areas of the Eden region where the potential land values from plantations are greater than the existing estimated land values. However, it was found that these returns were sensitive to changes in the market price for plantation products and the yields associated with plantation management regimes. Changes in international and domestic market conditions for both plantation and agricultural products can have an important influence on the potential share of land resources between competing uses.

Of the three plantation regimes considered, the radiata sawlog regime, generally, generated the highest plantation values followed by the radiata pulplog and the *E. nitens* pulplog regime in that order.

For the potential development of plantations in the Eden region to be realised, a significant level of investment in plantation processing will also need to occur.

There are a number of factors that need to be considered when contemplating plantation development. These will include economic returns and may include other factors such as prevailing institutional factors and environmental considerations. The importance of these factors in investment decisions can vary depending upon the type of investor. For instance, the rate of return required to justify plantation investment may vary between industrial companies and individual investors, such as farmers. In addition, some investors may place greater importance on the environmental and lifestyle costs and benefits associated with plantations in their investment decisions. Government based investment may consider determining the socially optimal level of investment in plantations.

The long term nature of plantation investment and the large capital outlay required often means that individual investors do not have the portfolio flexibility of companies. For these reasons, it is not possible to determine the extent of plantation development in the region in the short to medium term, even though plantation returns may exceed the returns from existing agricultural uses. However, in the long term economic forces should eventually result in the conversion of land to plantation forestry wherever the private returns exceed those from agriculture and other activities, though other factors such as market imperfections or regulatory considerations may impede these investments.

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