Identification of Plantation Expansion Opportunities in New South Wales

Southern NSW CRA

A project undertaken as part of the NSW Comprehensive Regional Assessments

January 2000

IDENTIFICATION OF PLANTATION EXPANSION OPPORTUNITIES IN NEW SOUTH WALES

SOUTHERN NSW CRA REGION

Bureau of Rural Sciences,
in Conjunction with
State Forests New South Wales and
Australian Bureau of Agricultural and
Resource Economics

A report to the NSW CRA/RFA Steering Committee
as part of the
NSW Comprehensive Regional Assessments
project number NA07/ES
January 2000

For more information and for information on access to data contact the:

Resource and Conservation Division, Department of Urban Affairs and Planning

GPO Box 3927
SYDNEY NSW 2001

Phone: (02) 9228 3166
Fax: (02) 9228 4967

Forests Taskforce, Department of the Prime Minister and Cabinet

3-5 National Circuit
BARTON ACT 2600

Phone**:** 1800 650 983
Fax: (02) 6271 5511

ISBN 1 74029 001 1

This project has been jointly funded by the New South Wales and Commonwealth Governments and managed through the Resource and Conservation Division, Department of Urban Affairs and Planning, and the Forests Taskforce, Department of the Prime Minister and Cabinet. The project has been overseen and the methodology has been developed through the Economic and Social Technical Committee which includes representatives from the New South Wales and Commonwealth Governments and stakeholder groups.

Report Project Team
This report was produced through the cooperation of BRS, SFNSW, and ABARE. The following are the major contributors to the project.
Bureau of Rural Sciences
Phil Tickle (project manager)
Michael Ryan
Susan Hafner
Antti Roppola
Tamara Abed
Alison Pritchard
Sabrina Sonntag
State Forests New South Wales
David Cromarty
Michael Welch
Bob Bridges
Bruce McGee
Sally Arundell
Australian Bureau of Agriculture and Resource Economics
Economics
Allan Hansard
Kevin Burns
Other
John Hindle – NSW Dept of Agriculture

Acknowledgments
This report relied on assistance and information from a number of sources, without their help this project could not have been completed.

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PROJECT SUMMARY

This report describes a project undertaken as part of the comprehensive regional assessments of forests in New South Wales. The comprehensive regional assessments (CRAs) provide the scientific basis on which the State and Commonwealth Governments will sign regional forest agreements (RFAs) for major forest areas of New South Wales. These agreements will determine the future of these forests, providing a balance between conservation and ecologically sustainable use of forest resources.

As part of the Comprehensive Regional Assessment (CRA) process, a study was conducted to identify areas suitable for plantation development in the Southern NSW Regional Forest Agreement (RFA) region. The study was confined to cleared private land and consists of three parts: capability, suitability and economic analysis. Plantation potential was determined for one softwood species; Radiata Pine (*Pinus radiata)* and one hardwood species; Shining Gum (*Eucalyptus nitens)*. These species were chosen on the basis of a stakeholder workshop and the existing industry structure.

An examination of existing literature found previous studies to have limitations, such as a lack of comprehensive economic analysis, use of very coarse data, restricted coverage within the RFA region, qualitative (descriptive) rather than quantitative analysis, or a lack of maps showing the location of potentially suitable land or the lands' productivity ranking.

The study also took into account the existing resource of 180 000 hectares which is almost exclusively *Pinus radiata*. The 1997 harvest from this resource was 1 313 000 cubic meters of sawlog and 563 000 tonnes of pulpwood per year. For sawlog this has potential to increase up to 1 483 000 cubic metres per year by 2002 and up to 1 583 000 cubic metres per year by 2020. Pulpwood is estimated to increase up to 987 000 tonnes per year by 2002 and then drop to 792 000 tonnes per year by 2020, as short term availability of pulpwood exceeds long term sustainable level due to backlog of thinnings.

The major areas of current plantation include the Tumut/Tumbarumba resource in the Tumut sub-division and the Bathurst – Oberon resource in the north sub-division. The ACT resource was excluded from this study.

The physical capacity of the area was assessed using the joint BRS/CSIRO developed model 3PG (Physiological Principles for Predicting Growth). The model predictions were then validated by experienced SFNSW personnel and provided to regional plantation committees in Southern NSW and the Economic and Social Technical committee for comment.

The model predicts potential growth using biophysical factors of soil type, temperature, solar radiation and elevation. 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 1.66 million hectares out of 3.22 million hectares of cleared private land were identified as capable of growing *P. radiata* plantations. Of this 26 per cent (432,000 hectares) was rated of medium productivity potential or higher and the remaining 74 per cent was rated low productivity potential. For *E. nitens*, approximately 326 000 hectares were identified as capable with about 30 per cent (98,000 hectares) of this area rated medium productivity potential or higher.

A matrix of differing price and cost structures was analysed to assess the impact of changes in expected yields, expected returns and establishment costs. The economic analysis undertaken by ABARE, identifies potential to expand the softwood plantation resource, with approximately 163 000 hectares having a higher economic value than the existing land use. In contrast hardwood plantations showed very little potential, with only 1300 hectares economically suitable under the most optimistic scenario.

Overall, this study found that there are significant areas in the Southern CRA/RFA region where the potential net present values under softwood plantation is greater than existing estimated net present values. Apart from economic returns, other factors such as planning regulations and perceived environmental advantages/disadvantages will undoubtedly influence many plantation development decisions. In addition there is a 30 000 hectare requirement within the Tumut sub division for *P. radiata* expansion as part of the new VISY plant. This study shows that capable land is potentially available for this expansion within the Tumut sub division. Hardwood sawlog plantations show limited economic potential for broadscale plantings under current economic regimes.

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 hectares of hardwood plantations in 1999-00 and to eventually double the existing area (200 000 hectares) 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 Southern CRA region that are capable of meeting the government's objectives and to provide 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; and

scale and proximity to existing and potential markets;

In order to identify total potential wood flows 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 considering incompatible land uses, and other practical limitations on plantation establishment.

The basic concept underlying capability modelling 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 modelling looks at the more realistic aspects of whether sites identified as being capable of growing plantations are suitable from an existing vegetation, environmental (slope), and land use 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 Southern NSW CRA regions are shown in Map 6.a.

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. Within the Southern CRA region are many commercial *P. radiata* plantations on sub-optimum sites, especially the Kowen plantations just east of the ACT towards Braidwood on a rainfall of 500-550 mm pa. These plantations, provide the lower bounds for plantation establishment.

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.

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. In this study suitability excludes the comprehensive economic analysis which is addressed in the economic analysis chapter.

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 clearing controls under the NSW *Native Vegetation Conservation Act 1997*. Consideration needs to be given to the potential conflict with other land uses and to the political and social implications of various options.

1.4.6 Economic analysis

The economic analysis compares a plantation land use with the existing agricultural enterprise. While changes in land use are sometimes associated with non-economic values, the predominant driver for land use change is economics.

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 *Native Vegetation Conservation Act 1997* .

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 had been limited until the late 1990s. According to Ferguson (1997), this was 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. This has been evidenced by broad scale pulpwood plantation expansion in South West Western Australia, the Green Triangle of Victoria and sawlog and pulpwood plantation expansion in Northern NSW. . 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:

- Boost the availability of suitable land;
- Get the commercial incentives right to enhance the development of the plantation growing and processing industry;
- Establish a commercial plantations culture; and
- 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 New South Wales Government's commitment to plantation development led to the *Timber Plantations (Harvest Guarantee) Act, 1995,*subsequently repealed by the *Plantations and Reforestation Bill (1999)*. The objects of the Plantations and Reafforestation Bill, enacted in December 1999, are:

- to facilitate the reforestation of land;
- to promote and facilitate development for timber plantations on essentially cleared land;
- to codify environmental standards, and provide a streamlined and integrated scheme, for the establishment, management and harvesting of timber and other forest plantations, and
- to make provision relating to regional transport infrastructure expenditure in connection with timber plantations,

consistent with the principles of ecologically sustainable development.

The Plantations and Reforestation Act (PRA) was introduced in response to several planning issues recognised as constraining plantation development in NSW. Previously more than 10 licences, approvals or permits under were required for plantation development to proceed. The PRA provides an integrated consent framework through a State-wide Code of Practice to be introduced by mid-2000, and aims to improve consent time frames with the Department of Land and Water Conservation as the single consent authority. The legislation also deals with infrastructure planning by providing a system for industry contributions with payment delayed until the expenditure is required in connection with harvesting. Timber harvesting and other activities are guaranteed for authorised plantations. The PRA makes the distinction between industrial plantations (>30ha) and farm forestry, which is exempt from the Act except where it involves clearing of native vegetation or of protected land, amongst other things.

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 VISY Industries development in Tumut, 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 Plantation Committees and Farm Forestry Networks have also been active in encouraging councils to adopt a uniform and positive approach to plantation development.

3. EXISTING PLANTATIONS

3.1 PLANTATION TIMBER RESOURCE AVAILABILITY

There are approximately 180 000 ha of exotic softwood plantation in the Southern CRA region, of which 48 000 ha are privately owned with the balance being state-owned and managed by State Forests of New South Wales. This figure includes approximately 13 500 ha of land which is awaiting re-establishment following clearfelling or failure in the first rotation.

The Region also surrounds the Australian Capital Territory which has a total of about 15 000 ha of Government-owned exotic softwood plantations. While the ACT is not included in the region, they have no capacity for expansion and are actively promoting establishment of plantations in the Southern Tablelands to supply mills in the ACT.

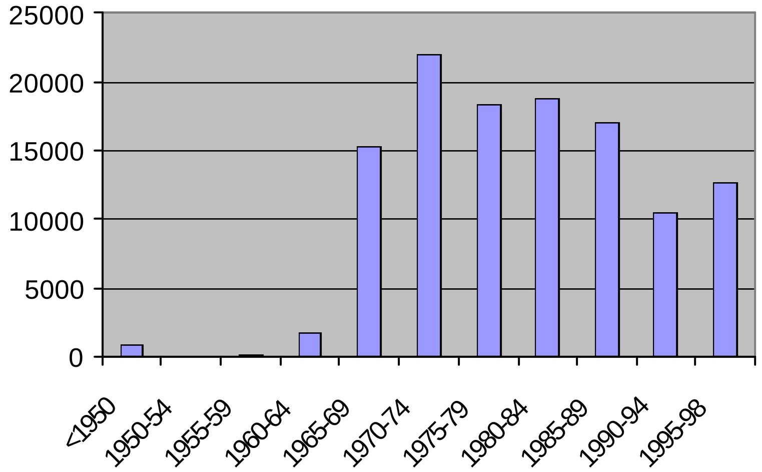
Radiata Pine plantations dominate the plantation resource with over 98% of the above area. There are also some Douglas Fir (*Pseudotsuga menziesii*), Ponderosa Pine (*Pinus ponderosa*) and Corsican Pine (*P. nigra*). In comparison with the above figures, the area of hardwood plantation in the region is negligible.

The state-owned plantations include large areas which were established in the late 1960’s and early 1970’s under Commonwealth-State Softwood Forestry agreements and another peak around 1985. The earlier peak has now entered its scheduled clearfelling stage. Annual plantings were reduced during the period 1990 to 1994 and have not yet reached the levels seen in the 1970’s and 1980’s.

Private plantations are comparatively younger with a significant impetus coming from the establishment of Australian Newsprint Mills at Albury in 1981 and beginning in 1984 that company’s foray into its own and joint ventured plantations.

An agreement between the NSW State Government and VISY Industries will lead to the establishment of a further 30 000 ha of *Pinus radiata* in the Tumut area, on mainly cleared agricultural land, over the next ten years to support a major new kraft pulpwood industry at that location.

Figure 3.a - Areas of State owned softwood by planting period.



source SFNSW

3.2 FOREST PRODUCTIVITY

The current State Forests of NSW estate has an average M.A.I. of about 18 m^3/ha/year, of which sawlogs make up about 12 m^3/ha/year. This approximate average is made up of a range from some lower growth rates on poorer sites and earlier second rotation sites to later age classes using improved genetic material on highly fertile ex-pasture sites with full site preparation. Average M.A.I. is expected to improve as newer plantations replace and supplement existing ones.

TABLE 3.A - SOFTWOOD RESOURCE VOLUMES FROM STATE FORESTS' PLANTATIONS IN THE SOUTHERN CRA REGION

	Sawlogs (m^3) per annum	**Pulpwood (tonnes) per annum**
Current harvest	1 313 000	563 000
Potential harvest 2002 [a,b,c]	1 483 000	987 000
Potential harvest 2020 [a,b,c]	1 582 000	792 000

a) Potential 2002 level of yield based on current plantation resource including an expansion of 30000 ha. at Tumut over the next ten years
b) Sawlog availability predicated on the sale of all pulpwood.
c) Potential yields represent sustained annual levels when normal age class distribution is achieved (even areas of all age classes). Short term availability of pulpwood exceeds long term sustainable level due to backlog of thinnings.

Source SFNSW

Table 3A 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 harvest in 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 potential harvest in 2020 is based on the expansion program currently underway to provide pulpwood for VISY Industries as well as existing commitments

Yield regulation:

The system used by State Forests is based around yield tables. The yield table contains potential wood production over to time, given a prescribed silvicultural regime. Yield type can be derived number of ways. The FRI (Forest Research Institute) New Zealand software product known the as STANDPAK is used to model silvicultural regimes and produce a yield table.

The yield table is then assigned to compartments. The resulting file is then imported into a linear program interpreter and solved. The solution reports on long term sustainable wood flows and takes into account estate constraints. These constraints include long-term wood supply agreements and minimum clearfell ages for yield tables. The softwood yield tables used in this project are shown within Appendix 5.

Inventory:

The inventory system used by State Forests of NSW is called MARVL, (Method of Assessment of Recoverable Volume by Log Grades) from the FRI New Zealand. This system relies on temporary plots where all trees are measured for dbhob (diameter breast height over bark) and log quality factors are recorded. The inventory results can indicate growth rates and potential volume recoveries. The inventory results are used as a basis to monitor harvesting yields.

3.3 PLANTATION FOREST SILVICULTURE

Establishment

General site preparation on first rotation sites is as follows:

- Line ripping (spot cultivation on steeper sites) to 600mm.
- Aggressive grass control through knockdown and residual herbicide application.
- Genetics matched to site conditions (e.g.) cuttings
- Hand or machine planting

General site preparation on second and subsequent rotations are as follows:

- Chopper rolling or burning of residual slash depending on amount of slash from first rotation
- Line ripping, or spot cultivation with excavator on steeper sites, to 600mm
- Aerial spraying with herbicide to reduce competition
- Hand or machine planting

Management

First thinning operations are normally carried out at about age 13 or 14 although many stands have had delayed thinning histories due to the lack of a reliable pulp market. Stands which are thinned on time would normally have a second thinning at about age 21 followed by a third thinning at about age 28 and a clearfelling at about age 33 to 35. The trend is towards two thinnings rather than three and an earlier clearfelling age.

Stands which are subjected to a delayed thinning regime would normally have only one thinning at about age 17 to 20 followed by an earlier than normal clearfelling (age 28 to 30) while stands which remain unthinned (e.g. on steeper sites) would also be subjected to an earlier clearfelling.

Fertiliser is limited to post thinning booster applications applied to the most productive sites and remedial boron treatment at an early age where the soil is deficient in that mineral.

Pruning is carried out on the higher productivity, generally ex pasture sites, which may have excessive side branching if left unpruned. The aim being to control branching on the first 6 metres and provide a better economic return on the high productivity sites. This will ultimately produce high value clearwood (wood without branch knots).

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 Southern NSW CRA regions. 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 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.

4.2.2 Review of Burns, K., Walker, D. and Hansard, A. (1999) Forest Plantations on Cleared Agricultural Land in Australia: A Regional Economic Analysis

This is a national study, looking at present and future competitiveness of plantation and farm forestry investments for a range of final products. The ABARE study considered land productivity and suitability along a national scale using National Plantation Inventory (NPI) regions as a basis. The study was aimed at developing the economic REAP (Regional Economic Analysis of Plantations) model, and therefore took a simplified approach to productivity analysis. The study ranked the productivity of cleared land by rainfall isohyets, independently assigning silvicultural regimes and yield tables for *Pinus radiata* within the Southern RFA region.

The study area

National Plantation Inventory regions of Australia, of which the Murray NPI region includes part of the Southern NSW CRA region.

Methodology applied

This study used the linear programming model, REAP to examine the competitiveness of plantation investments (expressed as net present value) compared to the estimated land values from present agricultural enterprises. Estimates of the forestry NPV was based on present industrial infrastructure, potential infrastructure, with and without a carbon market. This approach has limitations in that the estimated land values are based on farmers' responses, not actual market price. There is a temptation for any survey respondent to overstate or understate the price, depending on personal circumstances, and the report does not detail how the survey data was scrutinised.

Limitations

There are many biological factors which affect plantation growth and therefore potential, however this study looked only at rainfall. This makes it a very coarse study with substantial potential errors associated with species requirements outside of rainfall. The region does not cover the full Southern RFA region as it includes the Tumut sub-division and North sub-division, but excludes much of the South Coast sub division.

The REAP model is based on a number of assumptions including, using constant 1998 values and pre-tax basis for net revenue.

4.2.3 Review of SFNSW (1997) An evaluation of farm forestry land capability and suitability for *Pinus radiata* in the Central Tablelands, NSW. A report to Central Tablelands Farm Forestry Project

This study covers part of the North sub region of the Southern CRA region and was primarily a mapping exercise for capability and suitability of *Pinus radiata*.

The study area

The study covers the Central Tablelands region of NSW which is focused on the Bathurst/Oberon area of Southern/Central NSW.

Methodology applied

The capability assessment involved obtaining rainfall and soil landscape data for the region and then producing a capability rating based on the combination of these two data types. The study also looks at basic suitability criteria based upon commercially viable distance to current markets and future markets, existing timbered land, and unacceptable drought risk.

Limitations

The study essentially being a mapping exercise is not a comprehensive analysis of plantation potential. It considers *Pinus radiata* alone and covered only a portion of the CRA region and does not look into the suitability criteria in great detail.

4.2.4 Review of Jurskis (1996) Plantation land suitability assessment Southern Region. Prepared for SFNSW

This plantation land suitability assessment aimed to delineate and tabulate areas of land potentially suitable for timber plantations, both hardwood and softwood. This study also looked at existing work to assess potential areas and make a comparison between existing studies. It provides some very useful information including its recommendations that *Eucalyptus nitens* be used in the Tablelands regions. The study was not so clear in the coastal regions but cites other work suggesting *Eucalyptus saligna*, *Eucalyptus grandis*, *Eucalyptus nitens*, and *Eucalyptus smithii* as being the best volume producers and *Eucalyptus botryoides* as performing well in Nadgee State Forest. Concerns are raised as to patchy survival of eucalypts even in 900 mm rainfall regions and the final conclusions talk about the considerable doubt about the viability and growth rates of eucalypt plantations on the coast and tablelands. The study shows much less doubt about the potential for pine plantations and provides a very large potential area suitable for pine.

The study area

The study covered a large portion of the Southern CRA region from Bowral in the North extending south to the Victorian border and through to the Western extent bisecting the ACT. The region includes the Eden CRA region but does not include Tumut/Tumbarumba (the Tumut subdivision).

Methodology applied

Three primary physical criteria were used to define land potentially suitable for forestry plantations: land with slope up to 18 degrees and being essentially cleared with mean annual rainfall 750 mm for softwood plantations or 900 mm for eucalypt plantations. Crude estimates of consolidated areas were made using a dot grid on the GIS maps produced using the above criteria.

This study then looked at other work that had been undertaken within the region and made a comparison of predicted areas.

Limitations

While this is a very useful study, it does not cover the entire region as required through the CRA process. It also does not undertaken the capability and suitability analysis with the same level of detail as is undertaken in this CRA analysis and does not consider any economic analysis.

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

Some land capability and suitability work has been previously undertaken in the Southern NSW CRA regions. These studies have been conducted for various purposes, some of which have components highly relevant to this project.

Limitations of existing work included:

- 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 all capability and suitability factors; and
- that they did not all attempt to classify sites according to their potential productivity for plantations or specific species; 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.

Plantation capability assessment, therefore, identifies areas that are capable of supporting particular tree species. 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 analysis, 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 (see Chapter 4).
2. Identifying species for consideration, and collating data on their environmental requirements for growth and yield information from existing plantations within the Southern Study Area. See Appendix 3
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 potential growth for the selected species across the entire Southern region.

5.2 SPECIES SELECTION

Selection of appropriate tree species for plantation development 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 drawn upon, in addition to the findings of a workshop of key plantation interest groups held in Tumut 23 February 1998. The literature review of existing studies and findings of the plantation workshop are included in the appendices.

5.2.1 Purpose of the plantation

For the purposes of this assessment, the plantation establishment would be for medium to large scale plantations or wood-lots for long-term fibre and solid wood production. While many species can be grown to cater for niche markets, the large scale fibre and solid wood market is most close to the existing industry and most suited to a regional scale study. It is assumed, however, that areas capable of supporting high-yielding eucalypt species preferred for industrial use, might 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 Southern region 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 Southern region 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. A key requirement for economic plantation establishment is a market for thinnings (although some areas in the Southern Tablelands are planted with the assumption there will be no thinning market).

Harris Daishowa Pty Ltd. at Eden and Midway Pty. Ltd. in Geelong are the main facilities that will accept pulpwood from hardwood plantation thinnings. Well established markets are available for softwood thinnings in the Tumut sub division with the proposed VISY pulp facility and the medium density fibreboard industry in the North sub-division. The options are more limited within the South Coast sub division with some thinnings being utilised for treated poles.

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 Southern CRA region. As a result the capability study was limited to those species for which growth data are available.

5.2.5 Principal species in existing plantations

Existing softwood plantations within the Southern CRA region are almost exclusively *Pinus radiata*, with very small areas of hardwood plantations.

A number of species have been trialled on a limited basis within the Southern CRA and adjacent Eden region include:

- *E. agglomerata;*
- *E. globulus spp.;*
- *E. cypellocarpa;*
- *E. delegatensis;*
- *E. viminalis;*
- *E. nitens*
- *E. regnans*
- *E. botryoides*
- *E. pilularis*
- *E. maculata*
- *E. microcorys*
- *E. fraxinoides;*
- *E. dunnii;*
- *E. fastigata;*
- *E. globoidea;*
- *E. muellerana;*
- *E. nitens;*
- *E. obliqua;* and
- *E. smithii.*

For most of these species, there is insufficient quantitative information to describe species responses to changes in environmental conditions across the Southern CRA region. Analysis of these species is provided by a report titled, ‘The Growth of Eucalypt and Acacia provenances in the ACT and at Tallaganda NSW’ written by the Australian Tree Seed Centre, CSIRO, for the Southern Tablelands Farm Forestry Network.

5.2.6 Selected species

A workshop was held on 23 February 1999 to discuss a range of issues relating to the project. The workshop included representatives from SFNSW, DLWC, the Bureau of Rural Sciences (BRS), Australian Bureau of Agricultural Resource Economics (ABARE), Regional Plantation Committees, ACT Forests, local Council, farm foresters and industry. 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. globulus and P. pinaster* should be considered for the assessment.

Following detailed discussions at the workshop in relation to the quality of available growth and yield information, the following two species were recommended:

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

At this point in time there is only sufficient data available on growth rates and responses to climatic and edaphic variation, to make quantitative estimates of productivity, for these two species.

5.3 FACTORS AFFECTING PLANTATION GROWTH

The following four factors largely determine the growth and yield of plantations:

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. Chemically, the levels of phosphorous, nitrogen and potassium in the soil are 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 2.

5.4 ESTIMATION OF BIOPHYSICAL CAPABILITY - MODELLING METHODS

This study uses a process model to predict regional biophysical capability, however there are a number of methods which are summarised below and have been used in other studies. Four general approaches may be used to estimate biophysical capability:

1. **process models** : simulation of stand growth using environmental data and known physiological principles; produces outputs in a range of variables (eg stem volume, below ground

biomass, leaf area index) for a range of applications e.g. Tickle et al. 2000. More detail on the use of a process model follows in the next section.
2. **site index growth models** : based on long term plot measurement to determine species and site specific yield, defined by growth curves for a range of expected site indices (e.g. top tree height at a specified age). Tickle et al. 2000 compare results from both process and site index growth models.
3. **statistical models based on environmental data** : derived relationships between yield (species and site specific) and environmental inputs. An example of the use of a statistical method for prediction of *P. radiata* capability can be found in the Eden Plantation Potential report. BRS, SFNSW, ABARE (1998).
4. **classification approach** : reliant on selecting a good surrogate for the productivity of the species to be estimated e.g. naturally occurring vegetation and/or environmental enveloping using climate, soils, topography. A simple example is the use of annual rainfall to predict incapable, low, medium and high productivity. A classification methodology is used for prediction of *E. nitens* capability in the Eden Plantation Potential report.

5.4.1 *Process models :* 3PG-SPATIAL

For this study, the process model 3PG-SPATIAL (version 5, with interception and root partitioning modifications) was used to predict relative regional biophysical capability.
BRS and CSIRO developed the 3PG-SPATIAL model which is fully integrated into a Geographic Information System framework, from the process-based 3PG model (Landsberg and Waring, 1997) and its satellite version (Coops et al. 1998). The 3PG ("Physiological Principles Predicting Growth") model is based on a number of well-established biophysical relationships. These are used to determine forest biomass production from incident light, nutrients and water via the processes of photosynthesis and respiration. Total biomass is then allocated to different tree parts, such as foliage, stem and roots. The amount of foliage produced in turn drives photosynthesis in the next model time step.

3PG-SPATIAL runs in either Potential or Imagery Mode. The model is initialised with either satellite or user derived values of stand parameters. The physiological processes modelled rely on variables in a parameter file as well as soil and monthly climate surfaces. Default parameter sets exist for a number of species. The model processes for a nominated period e.g. 1970 to 2000 in monthly timesteps, in the following way:

3PG-SPATIAL : process model steps

1. Absorbed Photosynthetically Active Radiation (APAR) is calculated from radiation and Leaf Area Index (LAI)
2. The proportion of APAR that is utilised (APARU) depends on age, temperature and water availability
   - where water availability equals (rainfall - transpiration + soil water content)
   - which are a function of LAI, canopy conductance, radiation, soil water content and holding capacity
3. APARU, Canopy efficiency and the ratio of Gross to Net Primary Production (a constant value of approx. 0.45) are used to calculate Net Primary Production (NPP), which is the amount of dry matter or biomass accumulated
4. In Potential Mode, NPP is allocated to Stem, Branches, Foliage and Roots using partitioning ratios which are based on a surrogate for environmental conditions and allometric relationships. The stand undergoes self-thinning based on maximum mass per ha

5. In Imagery Mode, above ground biomass is calculated from NPP.
6. At the end of a month, new data are available and the above process is repeated.

Validation by field data or expert knowledge

Although one of the key benefits of developing process models is to be able to predict species productivity on sites for which no yield information is available, some verification of the outputs is necessary. Where field data are limited, expert judgement and local knowledge are relied on.

Regional studies are often performed for species which have not been established in the study area and so field data are lacking (or the field data are at a local scale, which is affected by microclimate and soil, not captured through input surfaces in the regional modelling process). Expert knowledge and opinion are therefore essential in the calibration and validation exercise to achieve a reliable prediction of relative productivity (i.e. low, medium and high categories) or absolute productivity.

Expectations of a regional study

3PG-SPATIAL Potential mode predictions of yield capture potential site productivity– they do not take into account events or processes such as disease, insect or fungal attack, wildfire or management history. Imagery mode can model the impact of these where their effect can be captured in satellite data input to the model.

The model, when correctly calibrated has been shown to predict relative productivity well at regional scale (Landsberg, 2000), and actual productivity well at a local scale (Tickle 2000). The information content of the inputs and outputs to the two scales should not be confused.

In the absence of yield information across the environmental envelope over which predictions are performed, a process model offers rigorous and informative data at strategic level. A tactical scale study based on finer data are necessary to refine predictions.

5.5 INPUT DATA

5.5.1 *Spatial inputs : Climate and soil data*

The model requires long term mean monthly climate data and best available soil data (refer tables 5a to 5b). Refer to Appendix 2 for summary statistics for climate surfaces by productivity class.

TABLE 5.A - LONG TERM MEAN MONTHLY CLIMATE DATA

Monthly long term mean rainfall	These data were generated by ESOCLIM at 250 metre raster resolution.
Monthly long term mean minimum and maximum temperatures	Generated by ESOCLIM at 250 metre raster resolution.
Monthly long term mean short wave radiation	Short wave radiation was generated by ESOCLIM at 250 metre raster resolution.
Monthly net radiation (additional surfaces derived from long term monthly mean surfaces)	Net radiation for each month was estimated from shortwave radiation by applying the equation derived from 25m topographically corrected data over Bago in SW NSW: netrad = 0.816 * swrad - 4.450

Frost days/month (additional surfaces derived from long term monthly mean surfaces)	Frost surfaces are calculated using an Australia-wide equation : frost days = -1.9 * mintemp + 15.2

TABLE 5.B - SOIL DATA

Fertility	The five class fertility data contained in the Department of Land & Water Conservation 1:100,000 scale soil landscape mapping (DLWC et.al. 1999) was reclassed as follows: Class Value Fertility 1 0.1 Very Low Fertility 2 0.3 3 0.4 4 0.5 5 0.5 Higher Fertility The fertility value used by the model is unitless, in the range of 0 to 1 and is not treated by the model as absolute but relative.
Soil water holding capacity	The Estimated Plant Available Water Holding Capacity (EPAWC) (millimetres of plant available water storage) from the Department of Land & Water Conservation 1:100,000 scale soil landscape mapping (DLWC et.al. 1999) was reclassed as follows: Input Range Output Value 0 to 50 50 50 to 100 100 100 to 150 150 150 to 200 200 200 to 250 250 250 to 300 300 300 to 350 350 350 + 400
Soil water power	Derived from the Fertility layer as follows: Fertility Soil Water Power 1 7 2 6 3 6 4 5 5 5 where Power represents the following categories : 9 for sand ; 7 for sandy-loam; 5 for clay-loam; 3 for clay.
Soil water constant	Derived from the Fertility layer as follows: Fertility Soil Water Constant 1 0.6 2 0.55 3 0.55 4 0.5 5 0.5 where Constant represents the following categories : 0.7 for sand; 0.6 for sandy-loam; 0.5 for clay-loam; 0.4 for clay.

The modelling exercise was performed for the Southern RFA region as defined by the RACD boundary (version 5 supplied on the 30th of September, 1999). The region comprises three sub-divisions : Tumut, North and the South Coast.

5.5.2 *Other inputs*

The model requires a number of parameters, many of which have standard, empirically derived default values, and others of which are derived in the calibration process.
The non-spatial inputs to the model comprise:

- general parameter values (e.g. run length, sample points for temporal sequences)
- values distinguished for softwoods and hardwoods (e.g. litterfall and density)
- species specific calibration parameters, particularly allometrics which determine partitioning of biomass to root, stem and leaf.

5.6 METHODOLOGY

5.6.1 *Calibration*

The primary goal of calibration is to alter the parameters (primarily the species specific variables) so that the yield predictions match the field data as closely as possible (i.e. comparisons of a particular variable at a particular point in time).

Joe Landsberg, one of the authors of the 3PG model performed the calibration for the two species considered. His own collection of *Pinus radiata* data was used to derive the calibration parameters for this softwood species. The absence of sufficient data for *Eucalyptus nitens* resulted in calibrations being performed using *E. delegatensis* data from the Bago State Forest (Tickle et al. 2000). *E. delegatensis* is felt to be reasonably similar to *E. nitens* in terms of temperature tolerances and biomass partitioning. The model refinement and validation stages offered an opportunity to address any differences in the two hardwoods (e.g. susceptibility to frost).

5.6.2 Model runs and refinement

Model runs were performed for *Pinus radiata* and *Eucalyptus nitens*. 3PG-SPATIAL produces output surfaces of continuous data for a range of variables. Stem volume at age 20 surfaces were classified into nine productivity classes and assessed during the refinement and validation stages.

Pinus radiata

Sample runs were completed for a subset of the study area that encompassed the major climatic variation across the region as well as key plantation locations identified by State Forests, NSW. This subset extended east/west from 147°E to 151°E and north/south from approximately 35°S to 36.5°S.

Initial runs were performed until the output surfaces reflected known productivity distributions in the area. Particular attention was given to the following patterns that should also be expressed by any model of the area:

- The Monaro plain: A dry, harsh area with extremely poor productivity;
- Goulburn: A rain shadowed area with noticeably lower productivity than adjacent areas;
- Tallaganda State Forest: A productive forest in an area of otherwise average productivity;
- Monga State Forest: A productive forest adjacent to large expanses of average productivity forest;

- Tumut region: Identified as some of the most productive forest in the study area.
- Kowen Forest: The *P. radiata* plantation at this location is felt to be marginal and indicative of a possible lower limit for plantation establishment with rainfall around 500-550 mm/year (Dave Cromarty, pers. comm.).

Model outputs were also provided to expert validators (State Forest, NSW and BRS) along with detailed 1:100,000 scale plots of nominated areas. The validators were asked to compare the results with site data and to report on any results that disagreed with site data or perceived productivity patterns in the area.

Temperature function: Early runs over-predicted some areas within the region. It was discovered that the optimal temperature was being set for the growing season average temperature (15 degrees) which was several degrees higher than the monthly average temperatures throughout the year at the same locations. The optimal temperature was set to 10 degrees (closer to the most productive sites' averages) resulting in a more realistic prediction of relative productivity.

Frost: The effect of frost on productivity was explored by comparing three scenarios (other parameters being equal):

- *Scenario 1 - Frost does not constrain productivity*: This resulted in productivity predictions in frost-prone areas being too high
- *Scenario 2 - Frost does constrain productivity and is defined by the Bago-derived equation*: This resulted in the reduction in productivity in frost-prone areas being too severe, significantly reducing the prediction in some of the highly productive areas in the Tumut sub-division.
- *Scenario 3 - Frost does constrain productivity and is defined by the Australia-wide equation*: The effect of frost days as calculated using the Australia-wide equation is a lot more mild and as a result, the productivity in and around Tumut/Tallaganda is better maintained while growth is still inhibited in the higher alpine areas.

Soil: The use of different soil fertility values was found to influence the magnitude of the productivity predictions but not the relative productivity across the region. When fertility was scaled between 0.1 and 0.9, the yield was much higher than expected. The final fertility surface was scaled between 0.1 and 0.5.

There was a problematic area in the Goulburn area where the soil water classification jumped a couple of classes across adjacent map sheets (this highlights some short comings in the DLWC soil mapping). On close inspection, different levels of absolute productivity resulted from the different levels of soil water input to the model. However, this did not affect the general regional trends in productivity throughout the region. This demonstrates that climate is driving regional trends in productivity predictions at this scale (250m input data) for this modelling exercise.

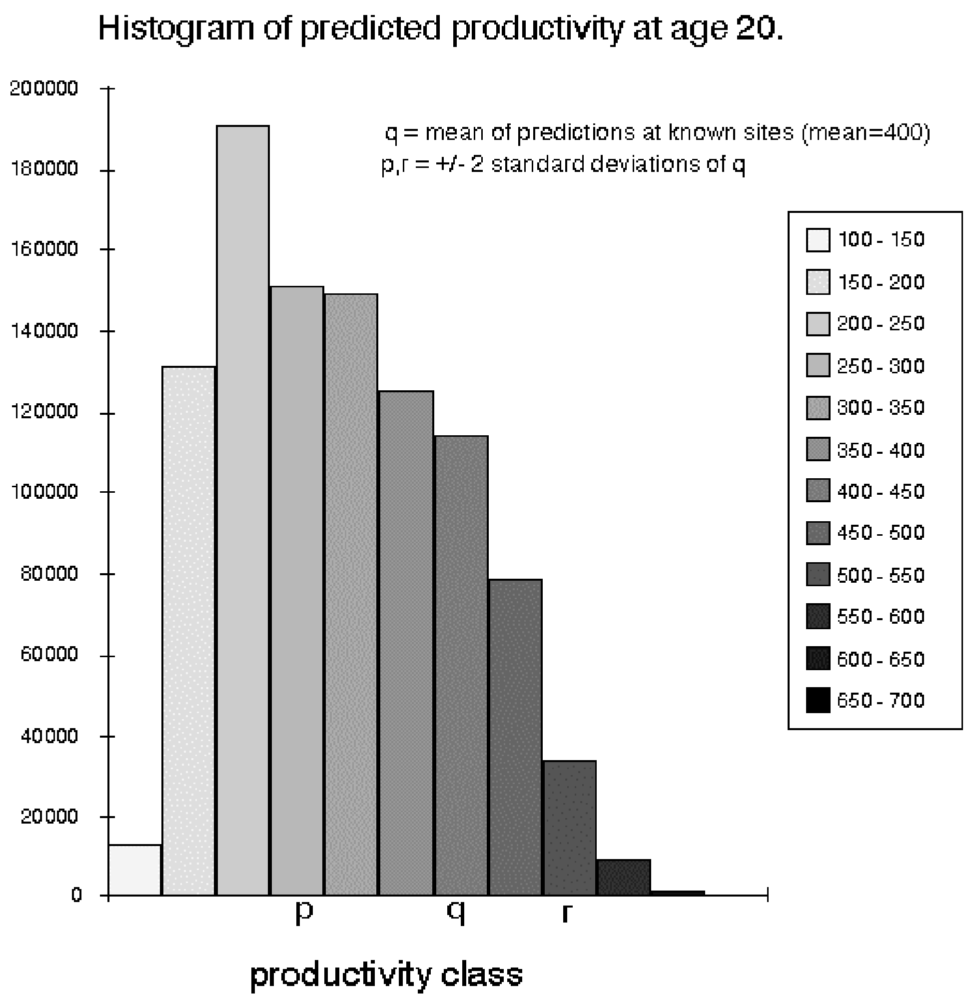
Predicted results compared with existing *Pinus radiata* plantations

The histogram in figure 5A shows how the area in the Southern region is distributed according to predicted standing volume. The histogram's Y axis shows the count of 250m cells each representing 6.25ha; the X axis shows the classified stem standing volume at age 20 in cubic metres per hectare. Data on plantations, provided for purposes of model validation by State

Forests NSW, is located in areas with predicted productivity ranging from approximately 340 to 510 cubic metres per hectare at age 20. It is to be expected that existing plantations occur in the medium to high productivity areas in the Southern region. While there may be plantations in the most productive parts of the region (up to approximately 700 cubic metres/ha), it is quite possible that these locations are urbanised or under agricultural land uses. Well over half of the modelled area is less productive than those locations where there was existing plantation validation data.

This strategic scale modelling exercise distinguishes the high, medium and lower productivity areas. It is necessary to perform a finer scale analysis such as at 25m depending on the terrain (e.g. using topographically corrected climate data), in order to model the local scale microclimatic and soil effects that influence actual tree growth.

Figure 5.a - Productivity distribution of final model run for *P. radiata*



Eucalyptus nitens

The *Pinus radiata* methodology, described above, of performing sample runs over a subset of the area to refine the model parameters, was applied in the case of the modelled hardwood. However there was very limited field data in the region against which to compare predictions, so expert opinion was relied on heavily to determine the best prediction of regional relative productivity. Comparison with satellite imagery of native vegetation meant that relative *E. nitens* productivity was easier to verify in areas without existing plantations than it was for *P. radiata*. An absence of plantation site data for *E. nitens* meant it was more difficult to determine commercial thresholds and absolute productivity than it was for *P. radiata*.

Four scenarios were run using optimum temperatures of 10 or 15 degrees and two sets of allometrics (parameters which guide the partitioning of biomass to stem, foliage and roots). Because the *E. delegatensis* allometrics used were derived from native forest rather than plantation sites, two runs were performed using high productivity allometrics (possibly more likely in an *E. nitens* plantation scenario) and also average productivity allometrics. The two sets of allometrics produced reasonably similar spatial distributions of relative productivity. The higher optimum temperature increased the relative productivity of the coast compared with the inland for both sets of allometrics. The absolute productivity from all four predictions had similar minimum values and frequency distributions, however the maximum standing volume at age 20 was highest under the higher allometric higher optimum temperature scenario and lowest under the average allometric lower optimum temperature scenario. In the absence of field data to support a particular scenario, the most conservative scenario was chosen.

5.6.3 *Expert Validation*

Once agreement on broad relative productivity across each region was achieved (with individual problem areas noted), the following validation steps are performed:

- **threshold where the species will not grow (commercially) :** Consider whether and how to account for any relevant factors e.g. low rainfall or temperatures, known problems in the classified soil surfaces
- **classify the relative productivity for each species into 3 classes** : low, medium and high productivity. Looking at the spatial outcome of varying the threshold between the three classes for each species made it easier to determine what that threshold was.
- **provide expected/estimated quantitative ranges (e.g. MAI) or indicative values and yield tables** for each productivity class. SFNSW approved yield tables (for all 3 productivity classes including thinning regime and expected yields for each species) are essential for economic modelling.

These validation aims are discussed under the following sections on: threshold; classification; quantitative ranges for productivity classes and individual problem areas.

Thresholds

.1 Waterlogging

Validators noted that areas around Jervis Bay and east of Nowra have severe waterlogging problems that preclude plantation establishment. 3PG_SPATIAL does not model waterlogging,

consequently higher soil water balance will result in higher productivity other things being equal. This results in over-prediction of productivity for areas suffering waterlogging, such as swamps. Soil landscape units from the DLWC soil landscape mapping that coincided with known problem areas were used to exclude these areas.
.

.2 Coastal Exclusion

All validators remarked on a widespread over-prediction of *P. radiata* productivity over coastal areas. This over-prediction was observed regardless of how the model was parameterised. The model produced similar patterns for *E. nitens*, which were felt to be an accurate representation of plantation productivity. This suggests an external factor limiting *P. radiata* that is not catered for by the *P. radiata* model parameterisation.
Areas along the coast where validators believed that *P. radiata* would not grow were excluded.

.3 Environmental thresholds

3PG-SPATIAL is a *potential* productivity model. Harsh environmental conditions will limit (or even stop) primary production, but growth will usually continue when conditions become favourable again. It is rare that the model will kill off the species using standard kinds of parameterisation and long-term average climate surfaces. Therefore, it is necessary to externally impose limits on the prediction that reflect mortality resulting from harsh conditions and actual climatic variability.

Booth & Jovanovic (1991) compiled generalised species requirements by a range of environmental thresholds. The spatial version of the ruleset for each was provided to the validators. In all cases the validators rejected these because they had plantations growing in the masked out areas.

As a result of this, other means were used to identify and exclude areas that validators believed would not support commercial plantations:

- One means of defining a biophysical capability threshold is using a value from the 3PG-SPATIAL productivity output. This is how the minimum limit for *P. radiata* was set, using the Kowen Forest pine plantation as a “landmark” point below which plantations were unlikely to be viable.
- Existing planting practices exclude areas that are likely to be at risk from environmental conditions. The 850 mm annual rainfall threshold was used as a minimum limit for *E. nitens* in keeping with established practice (Bridges, pers. comm.).
- Altitude limits were set for both species.
- Some areas adjacent Budderoo National Park that were identified by validators as having extremely poor productivity due to very poor geology (siliceous sandstone) were reduced from medium to low productivity.

TABLE 5C MINIMUM ENVIRONMENTAL THRESHOLDS

	Limit of variable	
	P. radiata	***E. nitens***

Minimum Total Annual Rainfall	500 mm	850 mm
Altitude	1350 metres	1450 metres

These thresholds and the resulting masks were agreed upon by validators as quantitative descriptions of the biophysical limitations of each species.

Classification

Once the above thresholds were agreed, the productivity surfaces for *E. nitens* and *P. radiata* were classified into low, medium and high productivity. Threshold values between classes were iteratively determined based on what the validators thought was appropriate and reviewing the spatial implications of the selected value against known plantations.

P. radiata

Low - Kowen Forest as lower productive limit as it is considered to be marginal.
Medium – Encompasses lower end of productivities in State Forest site data (less than mean)
High – Encompasses higher end of productivities in State Forest site data (greater than mean)

E. nitens

Low – Lower limit set at the 850 mm annual rainfall isohyet in line with current establishment practices.
Medium – Lower limit set low enough to ensure that productive stands in Monga and Tallaganda State Forests were separated from the lowest class.
High – Lower limit set low enough to ensure that productive stands in the Tumut region were separated from the middle class. Also adjusted to include the best stands that occur naturally in Tallanganda State Forest.

Individual Problem Areas

After completion of the model refinement and validation stages described above, the maps of predicted productivity for each species were sent to a wide range of individuals in forestry and plantation organisations. The general response was that they were a reasonable representation of where the species were expected to grow. The following issues were identified :

P. radiata

The high productivity areas south of Moss Vale and immediately west of the coastal exclusion are a result of the coastal influence on growing season length, however *P. radiata* is expected to perform poorly in some of these areas, as it does along the coast.

E. nitens

No individual problem areas were noted, however the limitations of a regional scale study and the need for a finer scale analysis to predict actual productivity were recognised. For example, there would need to be site specific factors taken into consideration in all areas but particularly on those areas of low capability. The important factor being the moisture availability of the site; planting being on those sites which are less exposed and therefore have better moisture (Bridges, pers. comm.). Slope and aspect effects on water balance are captured in finer scale topographically corrected climate surfaces.

Drought risk is a very important issue in marginal areas. The process of environmental thresholds described above is a simple way of removing areas where conditions are thought to jeopardise productivity. This could however be modelled by a number of methods, and should be, prior to site selection. Determining tolerable risk involves consideration of issues such as the timing and the nature of the drought in relation to plantation age, available soil water and evaporative demand, as well as commercial exposure and management options such as silviculture. For example, drought shortly after establishment is more likely to be lethal than the drought for mature trees. A better understanding is required of the effects of non lethal drought, as well as risk of drought death.

Quantitative ranges for productivity classes

Expert validators were not comfortable in assigning absolute values e.g. stem volume mean annual increment at age 20 to the classes derived from the previous stage. It was demonstrated that beyond a relative ranking, site specific issues such as soil and terrain introduce enough variability on a site by site basis to upgrade or downgrade any particular site by up to a class.

5.7 RESULTS

A majority of the area shown in each of the following capability maps will be masked due to suitability exclusions which are discussed in the following chapter. The gross capability surfaces are shown here to give a feel for regional trends in relative productivity over areas which are currently forested and readers will recognise.

The reader’s attention is drawn to the earlier section on the limitations of a regional scale study in “Expectations of a regional study”. Problem areas identified by SFNSW validators are discussed earlier. The following maps identify the highly productive nodes in the region. Areas identified as strategically promising should be modelled at a local scale, as limitations in the information content of regional input surfaces cannot be resolved. It should also be noted that the results give a far more realistic result than previous attempts to predict potential plantation extents using generalised national averages of simple climate thresholds.

5.7.1 General

It can be seen that in both cases, climate (especially rainfall) is the primary driver of regional productivity distribution. In both maps, large nodes of productive land can be seen in the two high rainfall areas, the Australian Alps and along the south coast. In both cases, areas with known low rainfall (the Monaro plains and North West of Yass) have been relegated to incapable classes. The model has also mapped out sub-regional nodes of productive land, such as the Oberon district and adjacent to the Shoalhaven river (i.e. Badja, Monga and Tallaganda State Forests).

For both species, it was found that species temperature functions had the greatest influence on relative distribution of productivity.

5.7.2 Pinus radiata

Problems with over predicting coastal productivity were noted earlier. Thus any high productivity areas east of the Great Divide should be viewed with caution. It is also important to highlight the importance of local scale variation in making enterprise level decisions regarding plantation establishment. For example, there are satisfactory *P. radiata* plantations in areas of the Monaro plain (otherwise considered a very poor plantation prospect) that rely on local scale variations in soils and geology that are not captured in inputs to a regional study of this kind.

MAP 5.a - Predicted Productivity of *P. radiata* across all Tenures

Map 5.b – Predicted Productivity of *P. radiata* on Cleared Private Land

5.7.3 *Eucalyptus nitens*

The overall capability of *E. nitens* is far less than for *P. radiata* due to the more stringent environmental exclusions applied. *E. nitens* is primarily restricted to the higher, cooler moister areas. With the exception of a small patch near Oberon, there are no apparent opportunities in the North sub-division.

Map 5.c – Predicted Productivity of *E.nitens* across all Tenures

Map 5.d – Predicted Productivity of *E. nitens* on Cleared Private Land

5.8 CONCLUSIONS

This strategic scale 3PG-SPATIAL analysis provides a reasonable regional overview of plantation capability for the study area. Regional scale model outputs are not precise at local scale. The model can identify regional patterns, but local variation is mostly driven by topographic position and/or soil attributes which are not precisely captured in regional scale input surfaces. A local scale 3PG-SPATIAL analysis can be expected to show topographic variation in yield and to model known field data.

In a recent joint study by BRS and CSIRO on the application of 3PG-SPATIAL at landscape scale in Bago-Maragle State Forest (Tickle et.al. 2000), predictions by 3PG-SPATIAL were compared with field data for 20 *E. delegatensis* plots aged between 16 and 87 years. Preliminary results indicate r^2 of 0.81 for predictions based on two detailed soil surfaces and $r^2$of 0.74 for predictions based on a constant value (mean of both surfaces).

6. LAND SUITABILITY

6.1 THE CONCEPT OF LAND SUITABILITY

In this study, suitability is the stage where practical limitations on plantation establishment are considered. While capability determines the inherent ability of a site to grow a given species, suitability reports on external factors that stop plantation establishment. For example, the majority of highly capable sites occur on incompatible land uses such as National Park or in areas of existing native forest. Suitability does not address economic factors, which are handled separately in chapter 8.

Availability of data are the primary determinant of how each criterion is treated. Where possible, spatial data are used to map unsuitable areas, however for a number of themes, insufficient or no data means that the analysis is limited to a non-spatial estimate. The data used for the analysis is presented below, grouped according to the type of data used.

6.2 AVAILABLE DATA

6.2.1 SPATIAL DATA:

The following data are available spatially for all, or a large part of the study area. This means that it is possible to determine the suitability of specific sites in relation to these themes.

RFA region boundary;

The version of the RFA boundary used was current on 30 September 1999 (version 5), from RACD (Resource and Conservation Division). This layer was used to define the study areas. The final RFA boundary was received after analytical work had been completed, therefore some (minor) differences can be expected in resulting area statements.

Land use and tenure

Land use is a composite dataset including information from; land tenure, local government and expert determination (John Hindle, NSW Dept. Agriculture).

Local government zonation is important in determining suitability of land and plantation development is highly dependent on these local government zones and Local Environment Plans. Most shires and councils have a Local Environmental Plan (LEP) which specify what land uses are allowed and restricted in certain zones. For instance, a zone classified as 1(a) (Rural A Zone) in the Shoalhaven City Council, has the objectives of protecting agricultural potential of rural land, and preventing fragmentation of viable rural holdings although agriculture and forestry in this zone requires no specific development consent. Zone 2(a1) (Residential A1 Zone) is primarily for detached housing and ensuring a range of other development permitted in a residential area is compatible with the residential environment.

Land use categories are outlined in Table 6.A, which were then classed on their availability for plantation agriculture.

TABLE 6.A - LAND USE BY AREA

		Area by Region (ha)			
Land Use	**Avail**	**South Coast**	**Tumut**	**North**	**Total**
Cattle Grazing	y	264 000	558 000		822 000
Coastal Grazing	y	4 000			4 000
Dairying	y	16 000	4 000		20 000
Extensive Cropping	y		14 000	26 000	40 000
Horticulture	n		3 000		3 000
Intensive Cropping	n		3 000	6 000	9 000
Mixed Grazing	y	442 000	566 000	1 111 000	2 118 000
Unavailable	n	148 000	81 000	11 000	240 000
Public Land	n	912 000	1 132 000	255 000	2 298 000
Rural Residential	n	4 000	27 000		31 000
Sheep Grazing	y		206 000		206 000
Unknown	y				1 000
Other private	y				
Total		1 789 000	2 594 000	1 409 000	5 792 000

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

- land tenure - 1:25 000 scale dataset delineating public land categories and private land;
- Land use mapping of the Upper Billabong Creek catchment done by the Upper Billabong Land and Water Management Plan Working Group. It covers two-thirds of the Holbrook Shire, done at a scale of 1:25,000;
- Local Environmental Plans (LEPs) from the shires of Tumbarumba, Oberon, Shoalhaven, Yarrowlumla, Eurobodalla, Tumut and Gunning;
- State of the Environment Report 1997;
- Road networks - 1:250 000 scale on private land provided by AUSLIG;
- 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 Southern NSW CRA region, as follows:

- Land tenure was used to provide a mask of public and private lands. With the public land masked out, it simply left the private land to focus on.
- Local government zoning (ie, Local Environmental Plans) have a significant impact on the capacity to establish plantations on private land. In the case of the Residential Use category of shire/council plans, local government zoning regulations restrict plantations establishment. Other zones prohibitive to forestry development include environmental protection zones, flooding zones and industrial zones. These areas, together with all public land, were masked out, excluding them from further analysis.
- Land use maps were provided for the shires of Holbrook and Snowy River. These were then converted into the land use categories of this study and incorporated into the land use layer.
- Satellite imagery was used to delineate land use in areas not covered by the land use maps of Holbrook and Snowy River. This was done in conjunction with a consultant (John Hindle) from NSW Agriculture, who categorised land use and validated at approximately the 1:100 000 scale.
- Broad land use maps of each shire from the State of the Environment Report, were used as verification of land use in the region.

Native vegetation from the Structural vegetation layer (RFA project name "CRAFTI");

The CRAFTI (Comprehensive Regional Assessment Aerial Photographic Interpretation) data consists of floristic and structural map layers for eucalypt dominant forest types, and includes areas of rainforest, special features and exclusions. As well as identifying non-forest native vegetation types not identifiable in ALCC (such as swamps and heath), the CRAFTI layer also fills in areas of ALCC that were not reliably identified as forest by ALCC and other vegetation types that may preclude plantation establishment (for example, rocky ground).

The Forest/Non-Forest item ("FNF") in the CRAFTI layer was used to generate a binary (yes/no) mask of forested lands. The special features item ("S1") was used to generate a binary (yes/no) mask of relevant special features. Special features selected are listed in Table 6B.

TABLE 6.B: CRAFTI SPECIAL FEATURES NOT SUITABLE FOR PLANTATIONS

Special Feature Code	Description
A	Bare ground, sand
AS	Bare ground, swamp
FP	Swamp Forest
FR	Riparian Forest
FW	Wattle
P	Existing Plantation
NS	Shade
Z	Coastal Complex
Y	Estuarine Complex
K	Rocky ground

R	Rainforest
S	Swamp/heath
T	Allocasuarina

The CRAFTI methodology focussed primarily on the mapping of vegetation on public lands. Specifications for minimum polygon size varied according to the attribute mapped. The minimum polygon size for eucalypt floristics was 10 hectares. Depending on specific structural characteristics, a minimum of 5 hectares or 25 hectares was required. Rainforest and rare forest types were mapped to a 2 hectare minimum.

Agricultural Land Cover Change (ALCC);

The ALCC dataset as described in Kitchin & Barson (1998) was the primary means of identifying existing woody vegetation on the assumption that clearing is not permissible for plantation establishment. While this layer gives complete coverage for the entire study area, noticeable underestimates of canopy cover in some areas means that ALCC is supplanted with the CRAFTI air photo derived forest/non-forest classification. The ALCC data does however, have a much smaller patch size across all tenures compared to the CRAFTI data. Table 6.C shows the types of land cover described by ALCC and how it is treated in this analysis.

TABLE 6.C - SUMMARY OF AGRICULTURAL LANDCOVER CATEGORIES (AFTER KITCHIN & BARSON, 1998)

ALCC Landcover Class	Availability	Description
0	Yes	Not classified
1	Yes	Pasture / Crop including herbfields, grasslands
2	No	Urban
3	Yes	Bare Ground
4	No	Water
5	No	Existing plantation
6	No	Orchard
7	No	Native or exotic woody vegetation
8	Yes	Clouds (not classified)

Steep areas;

In the Southern region the *Soil Conservation Act (1938)* generally classifies land with slope greater than 18 degrees as protected land which requires Department of Land and Water Conservation approval for harvesting. Therefore the National Parks & Wildlife compiled a 25 metre DEM (originally from LIC), used to derive a mask of areas with slope greater than 18 degrees.

Resulting patch size (calculated using the result of the above)

Elimination of unsuitable areas will fragment and bisect the gross productivity surface, to the point where the resulting areas are no longer large enough to warrant plantation establishment. After other spatial exclusions had been identified, a patch size analysis was applied to the result to discard any contiguous areas less than 25 hectares in size. While areas down to as low as 10 hectares may be planted, these are considered less suited to broad scale forestry usage and desirability by industry.

6.2.2 NON-SPATIAL DATA:

Incomplete, inadequate or non-existent data meant that the following suitability constraints cannot be mapped. The effects of these constraints are estimated where possible.

Remnant native vegetation;

Both the CRAFTI and ALCC have minimum limits on the size and type of native vegetation they can detect. A study conducted by Lamb (1999) studied 135,000 hectares of cleared farmland in the Upper North East region, and mapped the extent of remnant vegetation. The results for the study area in land classed by Structural vegetation and ALCC data as “cleared” suggest that approximately 40% of such land still contains significant native vegetation, see Table 6.D.

TABLE 6.D - REMNANT VEGETATION ON CLEARED PRIVATE LAND*

Class	Category	Canopy cover	Percent
1	Cleared	< 10%	61.5%
2	Scattered	10-80%	35.9%
3	Clumped	>80%	2.0%
4	Towns	N/A	0.6%
			100%

* Cleared land as identified by Structural Vegetation and ALCC datasets

Environmental Exclusions

In addition to retention of any significant areas of native vegetation in plantation design, codes of practice generally prescribe that drainage lines be buffered by an uncultivated distance of five metres each side of the drainage line. This prescription normally results in an unplanted zone of ten metres along drainage lines which can mean a minor reduction in plantable area, although this is difficult to quantify because it is linked with exclusions due to native vegetation, steep topography etc.

Other themes

Other themes which are known to influence suitability, but for which no suitable data was obtainable include:

- Utility easements (including powerlines, pipelines, roads, infrastructure)
- Native grasslands (other than those identified by Structural vegetation)
- Accessibility (proximity to roads or surrounded by inaccessible land uses)

MAP 6.a - Land tenure and land use

Map 6.b – Existing Plantations

7. DATA INTEGRATION

7.1 METHOD

Integration of the land suitability layers produces a composite land suitability layer. This composite layer can then be used to produce a simple binary (yes/no) mask that can be used to exclude land from an analysis if it is determined to be unsuitable by any of the input suitability themes. This final suitability layer can then be combined with the outputs of capability modelling to create a plantation potential layer that takes into account both predicted productivity and land suitability of any given area. The results of this process are utilised in the economic analysis in chapter 8.

7.1.1 Data preparation:

As ALCC land cover was both the most spatially detailed dataset, and the one that had the greatest net effect on the result, spatial data was rasterised to the same resolution and origin as the land cover layer. This avoids subsequent re-sampling errors and keeps all input themes in a common format.

7.1.2 Spatial masking:

All of the available spatially defined exclusions were combined into one composite layer with the results of the capability modelling. From this dataset, net capable areas were progressively calculated using the suitability themes in order that some measure of relative contributions could be determined. Once all the spatial prescriptions/limitations had been applied, the net productivity surface was then processed a second time to identify and to remove areas that result in patches less than 25 hectares in size.

7.1.3 Non-spatial information:

Other limitations on net suitable area were known to exist, but no suitable data could be obtained to spatially model their effect. Where possible, data was used to estimate what the effect of these suitability constraints might be. These estimates are listed below, but they have not been applied to the results as the overlap between the contributions cannot be easily determined, and there are still some themes for which estimates are not available.

Remnant native vegetation

As discussed in chapter 6, the area identified by ALCC and CRAFTI as “cleared land” still contains significant amounts of remnant vegetation in patches too small to be detected by either of these datasets. A study of remnant vegetation found that up to 40% of “cleared” land in the Northern NSW study area has significant remnant vegetation (Lamb, 1999).

Environmental Protection Agency (EPA) Pollution Control Licencing (PCL)

As discussed in the data section, between 8% to 14% of state forest compartments are set aside as filter and buffer strips to minimize disturbance near drainage lines and to provide areas in which infiltration will enable the deposition of any suspended sediments generated by harvesting activity. As these strips occur along waterways (which are frequently protected for other reasons), much of this area will be coincident and the net effect of PCL on harvestable (i.e. plantable) area will be much less. In Eden, the net contribution was 2% (See Eden plantation potential report 1998). Differences between State native forest management and private plantation management also mean that this value may not be directly comparable.

Electricity and other utility easements

Both major (supply) and minor (distribution) powerlines occur throughout the study area. There are also easements and structures for other utilities, such as water, gas and communication. No attempt has been made to quantify the effect of these exclusions.

Roading and infrastructure

As well as being required to give access to a planted area and being a prime determinant in distance to processing facilities/buyers, roading also has easements that can limit plantable area. No attempt has been made to quantify the effect of this exclusion.

7.2 RESULTS

Table 7.A and Table 7.B summarises the results, with class 0 not available, class 1 low potential, class 2 medium potential and class 3 being high potential.

TABLE 7.A: AREA STATEMENTS FOR *PINUS RADIATA* AND *EUCALYPTUS NITENS*:- SOUTH COAST AND NORTH

Pinus radiata

South Coast

Land Use	Avail	Class 0	Class 1	Class 2	Class 3
Cattle_Grazing	1	154 000	37 000	73 000	1 000
Coastal	1	4 000			
Dairying	1	15 000		1 000	
Extensive Cropping	1				
Horticulture	0				
Intensive Crops	0				
Mixed_Grazing	1	283 000	121 000	32 000	7 000
Not_Available	0	148 000			
Public	0	912 000			
Rural_Residential	0	4 000			
Sheep_Grazing	1				
Unknown	1				
un-differentiated_pri	1				
		1 520 000	158 000	106 000	8 000

North

Land Use	Avail	Class 0	Class 1	Class 2	Class 3
Cattle_Grazing	1				
Coastal	1				
Dairying	1				
Extensive Cropping	1	2 000	24 000		
Horticulture	0				
Intensive Crops	0	6 000			
Mixed_Grazing	1	393 000	585 000	127 000	6 000
Not_Available	0	11 000			
Public	0	255 000			
Rural_Residential	0				
Sheep_Grazing	1				
Unknown	1				
un-differentiated_pri	1				
		667 000	609 000	127 000	6 000

Eucalyptus nitens

South Coast

Land Use	Avail	Class 0	Class 1	Class 2	Class 3
Cattle_Grazing	1	197 000	49 000	13 000	5 000
Coastal	1	4 000			
Dairying	1	8 000	1 000	4 000	2 000
Extensive Cropping	1				
Horticulture	0				
Intensive Crops	0				
Mixed_Grazing	1	398 000	18 000	7 000	18 000
Not_Available	0	148 000			
Public	0	912 000			
Rural_Residential	0	4 000			
Sheep_Grazing	1				
Unknown	1				
un-differentiated_pri	1				
		1 671 000	68 000	24 000	25 000

North

Land Use	Avail	Class 0	Class 1	Class 2	Class 3
Cattle_Grazing	1				
Coastal	1				
Dairying	1				
Extensive Cropping	1	26 000			
Horticulture	0				
Intensive Crops	0	6 000			
Mixed_Grazing	1	1 082 000	11 000	15 000	3 000
Not_Available	0	11 000			
Public	0	255 000			
Rural_Residential	0				
Sheep_Grazing	1				
Unknown	1				
un-differentiated_pri	1				
		1 380 000	11 000	15 000	3 000

TABLE 7.B - AREA STATEMENTS FOR BOTH *PINUS RADIATA* AND *EUCALYPTUS NITENS:- TUMUT AND TOTAL AREA*

Pinus radiata
Tumut

Land Use	Avail	Class 0	Class 1	Class 2	Class 3
Cattle_Grazing	1	293 000	181 000	81 000	3 000
Coastal	1				
Dairying	1	1 000	3 000		
Extensive Cropping	1	10 000	4 000		
Horticulture	0	3 000			
Intensive Crops	0	3 000			
Mixed_Grazing	1	259 000	222 000	78 000	7 000
Not_Available	0	81 000			
Public	0	1 132 000			
Rural_Residential	0	27 000			
Sheep_Grazing	1	133 000	56 000	17 000	
Unknown	1				
un-differentiated_pri	1				
		1 942 000	466 000	176 000	10 000

Eucalyptus nitens
Tumut

Land Use	Avail	Class 0	Class 1	Class 2	Class 3
Cattle_Grazing	1	447 000	102 000	8 000	1 000
Coastal	1				
Dairying	1	3 000	1 000		
Extensive Cropping	1	14 000			
Horticulture	0	3 000			
Intensive Crops	0	3 000			
Mixed_Grazing	1	505 000	42 000	17 000	2 000
Not_Available	0	81 000			
Public	0	1 132 000			
Rural_Residential	0	27 000			
Sheep_Grazing	1	197 000	5 000	3 000	
Unknown	1				
un-differentiated_pri	1				
		2 412 000	150 000	28 000	3 000

Pinus radiata
TOTAL

Land Use	Avail	Class 0	Class 1	Class 2	Class 3
Cattle_Grazing	1	447 000	218 000	153 000	3 000
Coastal	1	4 000			
Dairying	1	15 000	3 000	1 000	
Extensive Cropping	1	12 000	28 000		
Horticulture	0	3 000			
Intensive Crops	0	9 000			
Mixed_Grazing	1	935 000	927 000	237 000	20 000
Not_Available	0	240 000			
Public	0	2 298 000			
Rural_Residential	0	31 000			
Sheep_Grazing	1	133 000	56 000	17 000	
Unknown	1				
un-differentiated_pri	1				
		4 127 000	1 232 000	408 000	23 000

Eucalyptus nitens
TOTAL

Land Use	Avail	Class 0	Class 1	Class 2	Class 3
Cattle_Grazing	1	645 000	151 000	21 000	5 000
Coastal	1	4 000			
Dairying	1	11 000	2 000	4 000	2 000
Extensive Cropping	1	40 000			
Horticulture	0	3 000			
Intensive Crops	0	9 000			
Mixed_Grazing	1	1 985 000	71 000	40 000	22 000
Not_Available	0	240 000			
Public	0	2 298 000			
Rural_Residential	0	31 000			
Sheep_Grazing	1	197 000	5 000	3 000	
Unknown	1	1 000			
un-differentiated_pri	1				
		5 464 000	229 000	68 000	29 000

7.3 PROPORTIONS OF LAND AVAILABLE FOR PLANTATION ESTABLISHMENT (ON INDIVIDUAL PARCELS)

Even though a large area of land may be capable 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 several ways, through a joint venture arrangement between the landholder and investor, outright purchase by investors or plantation establishment financed by the landholder. 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:

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

It is reasonable to expect that some land use categories could provide a greater proportion of land to plantation establishment than others. For example, intensive agricultural industries such as potato cropping, horticulture and dairying are economically sustainable around the Tumut/Batlow region. Consequently, less land, proportionally would be expected to be available for plantation establishment from this land use category compared with other land uses.

The alternative, purchasing land for plantation establishment, would also be strongly influenced by land use. Current returns from intensive agricultural industries ($ $ha^{-1}yr^{-1}$) are higher than those from other land uses, such land would therefore be expected to be higher. Intensive agricultural industries, by necessity, generally have more land improvements in comparison to other land uses, further adding to the overall land value.

8. ECONOMIC ANALYSIS

8.1 AIM

The purpose of this analysis is to assess the economic potential for plantation establishment in the Southern CRA 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. The potential returns from timber production are used to derive these plantation values. Environmental, agricultural and aesthetic costs and benefits associated with plantation development in the region are not included in the analysis.

This economic study aims to present the general competitiveness of several plantation regimes within the Southern NSW CRA region, and provide an indication of the various factors that promote and detract from this potential. While the information contained in this study includes potential plantation areas and yields, all parameters used to derive these results are of a general nature and therefore only of use at a strategic level. Plantation capability and suitability may differ at a local (or site specific) level.

The eventual level of plantation development within this region will depend on the full range of costs and benefits borne by the private investor. These may include not only the financial returns from plantation activities, but also other factors such as the influence of government regulations and environmental considerations.

This analysis follows on from previous research by ABARE (Burns, et al 1999), and uses refined information relating to land availability and land use, plantation capability and plantation yields. The derivation of this information is described previously in this report.

8.2 METHOD

The methodology used in this analysis has been described in Burns et al. (1999). Briefly, a discounted cashflow approach is used to determine the land values associated with the development of plantation forests in the region. The mill door prices of several potential mill developments were set to generate average stumpage values that equate to State Forests of NSW data, using transport costs calculated from each potential mill to all potential plantation sites.

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. It is assumed that equal areas of plantation are developed each year and that rotations are repeated in perpetuity to derive the potential value of land when used to grow timber plantations. For each plantation regime and productivity class, the rotation length was fixed prior to the economic analysis. 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.

8.2.1 Data and Assumptions

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

- Two plantation regimes are used in the region: a *Pinus radiata* sawlog regime and a *Eucalyptus nitens* sawlog regime.
- Six log types are produced from plantations in the region: small and large softwood sawlogs from thinned and clearfelled *P. radiata* plantations respectively, high quality large and high quality small hardwood sawlogs from *E. nitens* plantations, and pulplogs from both;
- Processing capacity for sawlogs is assumed to be developed in Tumut, Tumbarumba, Oberon, Canberra, Bombala, Holbrook, Wagga Wagga, Moss Vale and Batemans Bay. The mill door prices for these mills are derived from stumpage prices provided by State Forests of NSW. No account is taken of the potential rents and volumes available in the region to develop this capacity;
- Processing capacity for pulplogs is assumed to be developed in Tumut, Oberon, Wagga, Wollongong, Albury and Eden. As with the sawlog processing facilities, the mill door prices for these operations are derived from SFNSW stumpages and no account is taken of the actual potential to develop these facilities;
- The processing facilities used in the analysis and their cost and output characteristics are assumed to be continually repeated once they reach shutdown age;
- Individual plantation costs are independent of the size of investment, type of investor, individual site conditions, existing roading etc;
- Southern NSW is a small supplying region both for Australia and the rest of the world, such that forest product prices are independent of volumes produced in the region;
- Real prices for forest products and returns to existing agricultural land uses in the region are based on 1998 levels and are assumed to be constant forever;
- the estimated values of agricultural land used in the model are assumed to be proxies for the values from existing agricultural activities (excluding plantations) that compete against plantations; and
- A real discount rate of 7 per cent is used for all calculations.

For more information relating to the assumptions behind this modelling framework see Burns et al. (1999).

The current industry is able to process timber from the region principally consists of large scale sawmilling facilities in Oberon, Tumut and Tumbarumba, MDF and particleboard facilities in Oberon, Wagga Wagga and Tumut, and woodchip export facilities in Wollongong and Eden. As most of these facilities would be fully utilised with the existing plantation and native forest resource, additional capacity along the lines of those facilities described above would have to be developed to support an increase in the plantation area.

The main agricultural and grazing activities in the region area are beef and sheep grazing, with some dairying in the South Coast portion of the region and cropping in the North sub-division. 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 were derived from landholder's estimates of the value of their land. Spatial representations of these land values were derived by regressing this farm survey data on rainfall, the distance to urban centres and estimated land use.

8.2.2 Sensitivity analysis on key parameters

To take account of the variability surrounding forest product prices and yields associated with plantation development, especially hardwood sawlog regimes, sensitivity analysis was conducted on several key parameters relating to plantation potential. For this study the sensitivity analysis was conducted on parameters relating to stumpage prices, *E. nitens* plantation costs and *E. nitens* timber yields.

For the high price analysis, stumpage values for softwood sawlogs were increased by 10 per cent, from $33 to $36 per cubic metre for sawlog thinnings, and from $47 to $52 for clearfall sawlogs. Hardwood sawlog prices were increased by 25 per cent, from $20 to $25 for high quality small (HQS) sawlogs, and from $40 to $50 for high quality large (HQL) sawlogs. Pulplog prices were increased from $10 to $13 per cubic metre.

The low plantation cost analysis assumed that the *E. nitens* plantation costs were equal to data used in Burns et al. (1999), which are similar to SFNSW target costs for hardwood plantations. No sensitivity for this parameter was conducted for *P. radiata* as the values used are based on significant experience in these plantations in the region.

The high yield analysis was also conducted for *E. nitens* only, and assumes higher growth rates for plantations on each productivity class. Mean annual increments increased from $10m^3$/ha.y to $12m^3$/ha.y on low productivity sites, from $15m^3$/ha.y to $17m^3$/ha.y on medium sites and from $20m^3$/ha.y to $22m^3$/ha.y on high productivity sites.

8.3 RESULTS

Simulation results for combinations of the sensitivity analyses described above are presented in Table 8.A.

TABLE 8.A - POTENTIALLY ECONOMIC AREAS WITHIN ENTIRE SOUTHERN CRA REGION

P. radiata

Current Prices	Current Costs	High Prices **a**	WAPIS Costs	Base Yields	High Yields	Region	Economic Area	Sawlog Yield*	90-100% Area	Sawlog Yield*	75-90% Area	Sawlog Yield*
						North	59,392	579,810	2,561	19,020	7,321	68,844
✓	✓			✓		South Coast	6,862	82,453	8,325	82,030	8,743	82,588
						Tumut	9,764	108,351	62,888	522,879	188,830	1,494,197
						North	67,237	651,009	774	7,643	84,376	654,821
	✓	✓		✓		South Coast	17,161	183,976	6,016	57,326	11,725	89,228
						Tumut	78,407	688,060	86,506	696,565	214,135	1,705,355

a Stumpages prices for softwood logs increased by 10 per cent
* long term average sawlog yield post 2025 (given immediate establishment) – clearfall sawlogs only

E. nitens

Price	Current Costs **a**	High Prices **b**	WAPIS Costs **d**	Base Yields	High Yields **f**	Region	Economi Area	Sawlog Yield*	90-100% Area	Sawlog Yield*	75- Area	Sawlog Yield*
						North	0	0	0	0	0	0
✓	✓			✓		South Coast	0	0	0	0	0	0
						Tumut	0	0	0	0	0	0
						North	0	0	0	0	0	0
	✓	✓		✓		South Coast	0	0	0	0	0	0
						Tumut	0	0	0	0	0	0
						North	0	0	0	0	529	2,418
✓			✓	✓		South Coast	0	0	0	0	0	0
						Tumut	0	0	0	0	0	0
						North	0	0	258	1,179	2,201	10,062
		✓	✓	✓		South Coast	0	0	0	0	915	4,183
						Tumut	0	0	0	0	0	0
						North	0	0	0	0	0	0
✓	✓				✓	South Coast	0	0	0	0	0	0
						Tumut	0	0	0	0	0	0
						North	0	0	0	0	0	0
	✓	✓			✓	South Coast	0	0	0	0	0	0
						Tumut	0	0	0	0	0	0
						North	258	1,516	0	0	2,201	12,931
✓			✓		✓	South Coast	0	0	0	0	915	5,376
						Tumut	0	0	0	0	0	0
						North	1,282	7,532	1,177	6,915	58	341
		✓	✓		✓	South Coast	0	0	769	4,518	12,729	74,783
						Tumut	0	0	0	0	794	4,665

a SFNSW current costs for plantations ($2300 establishment, $185 maintenance)
b Stumpage prices for hardwood logs increased by 25 per cent
c SFNSW target costs for plantations ($2000 establishment, $90 maintenance)
d WAPIS plantation costs ($1400 establishment, $500 post-establishment, $80 maintenance)
e MAI's of 10 (low), 15 (medium) and 20 (high)
f MAI's of 12 (low), 17 (medium) and 22 (high)
* long term average clearfall sawlog yield (beginning post 2025 given immediate establishment) – HQL sawlogs only

8.3.2 *P. radiata*

Table 8.A and Map 8.a show that there is significant economic potential for additional *P. radiata* sawlog plantations in the RFA region. With the base parameters the total economic plantation area (where potential plantation values exceed estimated agricultural land values) is over 76 000 hectares.

The majority of these economic areas are located in the North sub-division (see also map 8a), south east of Oberon. The economic areas correspond to those areas found economic in Burns et al. (1999). A significant proportion of this economic area was located on medium productivity land.

Additionally, there is a similar area of land (74 000 hectares) that is almost competitive with the estimated agricultural values, especially in the Tumut sub division of the region where almost 63 000 hectares generates potential plantation values between 90 and 100 per cent of estimated agricultural values. These areas may have economic potential if additional benefits unrelated to timber returns can be derived from plantation development. Such benefits may include the amelioration of environmental problems, or the derivation of returns from other plantation products, such as carbon credits.

Because a significant proportion of this marginal area is located on lower productivity land, the potential additional timber flows from these areas are significantly lower than from the economic area (624 000m^3 of clearfall sawlogs compared to 770 614m^3 respectively). Nevertheless, given sufficient investment in processing capacity, the realisation of these marginal areas for plantation development could have significant implications for regional production and employment in the plantations sector.

The inclusion of higher stumpage prices for *P. radiata* logs also had a significant effect on plantation competitiveness in the region. Compared to the previous scenario, the economic area more than doubled to almost 163 000 hectares. Because much of this additional area was located on lower productivity land, however, the potential annual sawlog yields less than doubled to 1 523 045m^3.

8.3.3 *E. nitens*

Currently there are no significant areas of *E. nitens* sawlog plantations in the Southern NSW CRA region. Consequently, data relating to the potential yields from these plantations, the establishment and management costs of these and the potential stumpage values from the sale of timber are highly uncertain. To account for this several scenarios were modelled for *E. nitens*, with changes to key parameters as described above, see Appendix 4.

Table 8.A indicates that the base parameters are not sufficient to generate any development of *E. nitens* plantations in the region. *E. nitens* only shows potential (marginal at best) where lower plantation establishment and management costs are employed.

Hence the only scenarios that indicate any economic or near-economic potential (above 90 per cent of estimated agricultural values) are those where low plantation costs are combined with high stumpage prices and/or high timber yields. The most optimistic scenario (low costs, high prices and high yields) is presented in map 8b. This shows highest potential occurring in the northern part of the North sub-division, in areas similar to those identified as having potential for *P. radiata* plantations. In addition, a relatively large area is shown to have very marginal potential (generating values between 75 and 90 per cent of estimated agricultural values) east of Moss Vale.

It is important to note, that all the *E. nitens* scenarios presented in Table 8.A, indicate some potential, however, the aggregate areas involved are relatively small and have the potential to produce only small volumes of sawlogs. Consequently, the assumptions relating to the development of processing capacity used in this modelling framework would be invalid, as the volume of sawlogs would not be sufficient to encourage investment in processing capacity. Unless additional economic potential was present in the region or in neighbouring regions, it is unlikely that any investments in processing capacity would occur, and hence none of the areas indicated in Table 8.A and Map 8.b would prove to be economically suitable.

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.

Spriggins (1998) in a study undertaken in pine plantations in Western Australia estimated 114 people employed for a 50,000 hectares estate broken up into 28 people in the growing phase and 86 people in harvesting phase. This equates to one job per 1800 hectares in the growing phase and one job per 600 hectares in harvesting phase. This assumes no pruning will be undertaken.

An estimate for hardwood employment provided by Lancefield consultants (1995) and quoted in Spriggins (1998) was approximately 75 full-time jobs per 10,000 hectares of blue gum plantations with equal age classes ranging from 1 to 10 year-old clearfelled at age 10. The majority employment in this scenario is in the harvesting aspects.

The breakdown of employment is shown in Table 8B. It should be noted that this is based upon West Australian Blue Gum plantations for pulpwood and the labour requirements in harvesting and transporting will be different than with sawlog plantations.

In a study for SFNSW by CARE (1997) showed plantation industry employment estimated at 2.7 jobs per 1000 hectares in plantation establishment and maintenance, 7.8 jobs per 1000 hectares in harvesting and transport, and 46.5 jobs per 1000 hectares in milling in a steady state plantation resource.

In a report prepare for SFNSW on the impact of eucalypt forestry on the NSW economy, Regional Analysis and Strategies (1994) indicated a 100,000 hectare establishment would have direct employment impacts of 1867 persons. This includes 127 in forestry, 304 in logging and 1436 in processing.

TABLE 8.B - LABOUR REQUIREMENTS IN BLUE GUM GROWING, HARVESTING AND TRANSPORT

Activity	Full time employee equivalent per 10,000 hectares
Nursery-increment	1.2
Land evaluation and acquisition	1.4
Establishment	6
Tending	4
Inventory, harvest, planning	2
Administration and overheads	1.2
Other-roading etc.	2
Total growing	**17.8**
Falling and debarking	17.5
Snigging, forwarding logs to landing	15
Loading and transport of logs	12.5
Administration and overhead	5.5
Other	3.5
Total harvesting and transport	**54**
TOTAL employment	**74.8**

Lancefield consultants (1995)

MAP 8.a – Plantation Potential for *Pinus radiata*, Competitiveness against agriculture: baseline scenario

MAP 8.b – Plantation Potential for *Eucalyptus nitens*, Competitiveness against agriculture: optimistic scenario

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