Identification of Commercial Timber Plantation Expansion Opportunities in New South Wales

Upper and Lower North East CRA

A project undertaken as part of the NSW Comprehensive Regional Assessments

March 2000

IDENTIFICATION OF COMMERCIAL TIMBER PLANTATION EXPANSION OPPORTUNITIES IN NEW SOUTH WALES

UPPER AND LOWER NORTH EAST CRA REGIONS

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

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PROJECT SUMMARY

This project was undertaken as part of the Comprehensive Regional Assessments of native 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 the ecologically sustainable use of forest resources.

This study was conducted to identify areas potentially suitable for plantation development in the Upper and Lower North East NSW CRA Regions. The study consisted of three parts: capability, suitability and economic analysis and was focussed on cleared private land. The study examined two commercial softwood species: Slash pine (*Pinus elliottii*), and Hoop pine (*Araucaria cunninghamii*), and three native hardwood species: Blackbutt (*Eucalyptus pilularis*), Flooded Gum (*E. grandis*) and Spotted Gum (*Corymbia variegata*). As the study concentrated on the coastal areas within the region (where the majority of the native forest resource exists for CRA purposes), Radiata pine and tablelands hardwood species were not included in the assessment of plantation potential.

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

The Upper and Lower North East Regions contain approximately 47 200 hectares of hardwood plantation and 23 000 hectares of softwood plantation (including Radiata pine), managed by State Forests NSW. Additional plantations developed and managed by private landowners include 3 000 hectares of *Pinus elliottii*. The softwood timber industry in the region consists of two veneer and four sawmills. Approximately 170 000m^3/yr sawlog and veneer is available from the Upper North East, and a further 8 000m^3/yr from the Lower North East. The hardwood timber industry is in a transition from mature native forests to native forest regrowth and plantation grown hardwood timbers. In 1998-99 approximately 60 000m^3 of hardwood plantation material was processed by thirty-five mills across the region. An additional 80 000 m^3 of plantation residues were exported via Newcastle and Brisbane.

The plantation capability and suitability aspects of the study were conducted in parallel. Physical capability of sites to grow plantations was evaluated by using a modified and calibrated version of a physiological model (3PG-physiological principles for predicting growth). Suitability assessed the land in terms of its current land use and planning regulations. Current land uses were identified using satellite data and existing spatial data from various sources.

The economic analysis was undertaken using best available financial data to compare anticipated net present value from forestry with land price data collected from agricultural surveys. Several scenarios were developed to allow for variation in productivity, costs and returns from forestry. These scenarios included:

- two establishment and maintenance cost structures – (1) a relatively high cost regime likely to be encountered by small-scale enterprises, and (2) a lower cost regime possible in large scale development when economies of scale are achieved;
- two yield scenarios – (1) a baseline yield regime of between 15-22m^3/ha.yr total yield and (2) a more conservative yield regime of between 12-18 m^3/ha.yr;
- two stumpage price scenarios – (1) a benchmark price regime based on existing industry data, and (2) a 10% increase on the price of all product classes.

The analysis incorporated a competitive land price assumption which assumes that forestry had to completely displace existing land-use to access land. This is not always representative of the motivations and actions of landowners participating in joint venture schemes and land rental arrangements and those seeking non-market benefits such as bio-diversity, amenity or land protection. Consequently the development scenarios were presented against four land price categories (50-75%, 75-90%, 90-100%, >100% of land price) to allow some insight into the additional area of land that may be available to reforestation if these non-market benefits were accounted. Alternate financial analytical techniques such as internal rate of return, and the effect of financial returns from carbon sequestration are discussed.

In excess of 1.3 million hectares of cleared private land was identified as capable of growing the three hardwood and two softwood species, after excluding land not available due to steep slopes, incompatible land uses and meeting minimum productivity criteria.

The economic analysis demonstrated the sensitivity of the potential availability of land areas for plantation development to pricing and yield assumptions . For example, substantially more area is potentially available to broad-scale development than small-scale development due to the reduction in establishment costs associated with the broad-scale regime. Similarly, increased revenue from higher stumpage prices increases the potential area compared to lower stumpages. The impact of relaxing the competitive land price assumption in some cases increased the land area viable for plantations by over 1 million hectares. The Table below presents a summary of economic scenarios developed for the study and detailed in the report.

It is important to note that the study is undertaken at the strategic regional level and it is unsuitable for predicting plantation potential on individual properties. The study used the best available data and analytical techniques however the results suggest room for improvement, particularly in soils descriptions, and species productivity data for new areas such as the tablelands regions in the Western portion of the CRA region.

An alternative to the financial analysis would be to compare forestry returns with returns from existing enterprises. For example, the report suggests eucalypt plantations are capable of producing an internal rate of return of 7%, even on the lowest productivity site. This would compare favourably with returns from beef cattle and most dryland alternatives, and therefore could prove attractive to a landowner interested in diversifying existing enterprises without selling their property.

SUMMARY OF RESULTS NET AREA REDUCTION ARISING FROM VARIOUS LAND USE RESTRICTIONS, SHOWING BEST PERFORMING ECONOMIC SCENARIOS [(1)]

Capability/Suitability Criteria	Area (hectares) by Species		
	Hoop pine	Slash pine	Hardwood
Total Study Area	9 705 000		
Total area excluding non-productive and public land	1 920 000		
Total capable and cleared	1 572 000		
Total productive and suitable [(2)]	1 321 000	1 320 000	1 312 000
Total High productivity	275 000	412 000	272 000
Total Medium productivity	NA	730 000	396 000
Total low productivity	NA	178 000	644 000

Selected Economic Scenarios[(3)]	Land Price Options			
	>100% land value	90-100%	75-90%	50-75%
Slash pine broad-scale – high stump	166 000	83 000	275 000	558 000
Slash pine small-scale – high stump	0	4 000	160 000	241 000
Hoop pine small-scale - high stump	26 000	61 000	188 000	0
Hoop pine small-scale - base stump	0	26 000	217 000	32 000
Hardwood small-scale – high stump	13 000	25 000	262 000	767 000
Hardwood small-scale – base stump	0	10 000	90 000	753 000
Hardwood broad-scale – high stump	386 000	416 000	354 000	128 000
Hardwood broad-scale – base stump	152 000	286 000	604 000	216 000

(1) Areas determined from assumptions documented in report
(2) Area excludes individual parcels of productive land smaller than 25 hectares
(3) See Table 8D for details of remaining economic scenarios which include economics using conservative yield tables and base and high stumpage regimes.

1. INTRODUCTION

1.1 PURPOSE

The Comprehensive Regional Assessment (CRA)/Regional Forest Agreement (RFA) process includes an assessment of plantation development potential to either supplement existing resource to industry (if required), or to promote industrial and regional development.

The policy background stems from Commonwealth and State levels including the 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). In recent years the New South Wales State Government has funded a plantation expansion program aimed at promoting regional and industrial development, land repair and carbon sequestration values. On the north coast, Government policy was to expand the establishment rate of hardwood plantations through 1997-98 by a land purchase program and enhancing the existing share farming program for hardwood plantations. The policy also aimed to eventually double the area of softwoods through out NSW, focussing mainly in the existing pine regions in the south of the State.

The combined purpose of this plantation potential study was to investigate the feasibility of expanding the commercial timber plantation estate by identifying the land area in the Upper and Lower North East CRA regions that are capable of meeting the Government's objectives and to give an appraisal of the suitability of this land for commercial timber plantation purposes.

1.2 OBJECTIVES

To meet the purpose above, a set of 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.

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

The basic concept underlying capability 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 environmental and legal or planning viewpoint. The environmental considerations include slope and existing vegetation whereas planning considerations include the current land use and code of forest practice restrictions. From this viewpoint, cleared agricultural land only is considered.

The economic analysis utilises the areas determined through the integration of capability and suitability and undertakes a comparison of existing net present value of current land use compared with plantation land use.

1.3 SCOPE

The Upper and Lower North East NSW CRA Regions amount to a total of approximately 9.8 million hectares. However, in this study, a focus was given to cleared private land within this broader region. The regions are shown in Map 6.a. The study looked into broad-scale commercial timber plantation potential rather than niche plantation development opportunities, and as such, considered species already planted in large areas as suitable for further expansion.

The high diversity in sites of the UNE/LNE regions contrasts with other more uniform plantation areas such as the Green Triangle and South West Western Australia. The regions have a summer maximum rainfall pattern, with annual precipitation ranging from under 750 mm on the tablelands to over 1500 mm on some parts of the coast. Soil types are generally derived from coastal sands, sandstones, phyllites, granites and basalts. Landforms vary across the region. The coast is dominated by several major river valleys interspersed with moderate to steep ranges running to the tablelands. The tablelands are undulating reaching elevations in excess of 1100 m.

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 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, and as such, can be applied across all land tenures.

Land capability assessment does not include consideration of the social or economic evaluations of the various uses or consider the land availability which is covered under land suitability.

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).

In this study, land suitability assesses the practical considerations for commercial timber plantation establishment. This includes land tenure, existing forest cover, slope and parcel size. Whilst an area may be quite capable of growing trees it may be unsuitable due to the small area, excessive slope or existing forest cover. In this study, suitability excludes the comprehensive economic analysis which is addressed in the economic analysis chapter.

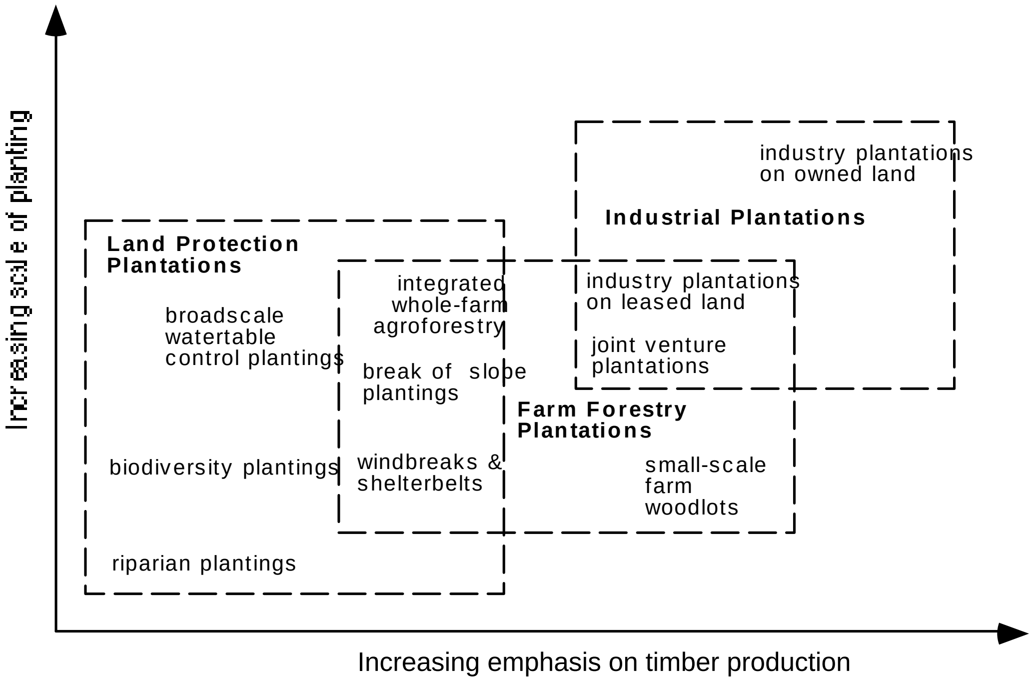
1.4.5 Availability

Land may not always be available for a particular use. The availability of land can and will be affected by environmental, social and political constraints. These may include threatened or vulnerable species, and highly erodible slopes and soils or community concerns regarding plantation management practices. In addition, there may be site specific factors which preclude the land being used in a certain way. These limitations cannot be identified in a broad regional study.

1.4.6 Small-scale and Broad-scale

Plantation size is a continuum from small-scale to broad-scale as seen in Figure 1.a, depending on its purpose. For this analysis, it was assumed a typical broad-scale plantation would be in excess of 1000 hectares, while a small-scale plantation would be less than 100 hectares. This distinction was used for costing scenarios in the economic analysis however, it should be noted that this is a somewhat arbitrary classification.

Figure 1.A – Plantation Scale and Purpose



Source: VicRFASC (1997)

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.

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 over the next decade.

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 regard 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 policy base for expanding Australia's plantations, but investment had been limited until the latter part of the 1990's, which saw the expansion of Blue Gum (*E. globulus*) plantations in South-west Victoria and South-west Western Australia. According to Ferguson (1997), this is poised to change as a result of work at State and local levels to remove disincentives to plantation investment, including freeing the sector from export controls. 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.

2.2.3 Plantations 2020 Vision

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

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

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

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

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

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

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

The two actions required to achieve this goal are:

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

2.2.4 Regional Plantations Committees

Three Regional Plantations Committees (RPCs) have been funded by the Commonwealth government to facilitate, coordinate and encourage the environmentally and commercially sustainable development of farm forestry, plantation and native forest resources, and processing and associated industries at a regional level. There are three RPCs working within the UNE/LNE CRA region– namely Northern Tablelands, Northern Rivers and Mid North Coast. The RPCs are also supported by the NSW Government primarily through the Department of State and Regional Development and Regional Development Boards.

Broad regional stakeholder representation is present on the Committees, including State agencies, regional development groups, landholders, timber processors, conservation groups, consultants, and research institutions.

Issues currently being addressed include regional planning, infrastructure and coordination, undertaking feasibility studies, development strategies and formulating related marketing, investment and wood flow plans.

2.3 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.

The NSW Government’s 1999 policy “Our Forests: The Right Balance” identifies a number of initiatives for the period to 2004 including:

- the continuing growth in the hardwood and softwood plantations program,
- encouraging private investment to increase hardwood plantations by 10 000 hectares per year and
- providing funding of $30 million for a further 10 000 hectares of hardwood plantations to be developed over five years on the north coast.

The State Government's commitment to facilitating plantation development has led to the *Plantations and Reafforestation Act (1999)* which will incorporate the provisions of the *Timber Plantations (Harvest Guarantee) Act (1995)*. The objectives of this Act are:

- to facilitate the reafforestation of land;
- to promote and facilitate development of timber plantations on essentially cleared land;
- to codify existing environmental protection standards, and provide a streamlined and integrated scheme, for the establishment, management and harvesting of timber 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 (1999)* was introduced to streamline planning for plantation development in NSW. The Act provides an integrated consent framework through a State-wide Code of Practice to be introduced by mid-2000. The Act will be administered by the Department of Land and Water Conservation, and stipulates specific timeframes for assessment of applications for authorisation. The *Plantations and Reforestation Act (1999)* 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 *Plantations and Reforestation Act (1999)* makes the distinction between plantations (>30 hectares) and farm forestry, which is exempt from the Act except where it involves clearing of native vegetation or of protected land.

The State Government has also signed a Memorandum of Understanding with VISY which commits to the establishment of 30 000 hectares of softwood plantation areas strategically located near new industrial developments in southern New South Wales.

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

2.3.1 State Forests' Plantation Program

Hardwood plantations

Initially funded by government, the State Forests hardwood plantation program has sought to maintain a high level of expansion whilst progressively replacing its government funding base with private investment as well as developing the infrastructure and capacity to support an efficient and competitive planting program. There is an increasing focus on developing plantations on private land in conjunction with landowners.

The resource provided by the hardwood plantation program will underpin and facilitate the transition of the traditional native saw milling industry through the supplementation of timber resource from native forest. The timber industry on the north coast is currently in a transitional phase as the predominantly mature native forest resource is supplemented with younger regrowth native forest and intensively managed plantation grown material. Appendix 8 provides a description of quantitative analysis of the SFNSW resource.

The emphasis of the program to date has been on the production of sawlog material, particularly smaller size sawlogs. However, the program has also sought to develop industrial capacity for value adding younger aged plantation grown material. In addition, a range of potential new products are in various stages of development, as described subsequently.

Softwood plantations

Recent expansion in State Forests’ softwood plantations has been largely self funded. The focus of softwood plantation activity in the UNE/LNE is primarily on Radiata pine on the northern tablelands and Slash pine in coastal areas. Currently there are no softwood joint ventures in the UNE/LNE CRA region.

Other services

In March 1999, an Investment Memorandum (IM) was announced by the NSW Government involving State Forests, Bankers Trust and the NSW Treasury with State Forests being the plantation service provider. The Memorandum offered investment opportunities to companies based on joint wood-carbon production. The Tokyo Electric Power Company (TEPCO) signed contracts in February 2000 as the first major customer under the IM. The contracts allow for the planting of between 10,000 and 40,000 hectares over ten years, with 1,000 hectares to be planted in the first year. The Information Memorandum has recently been re-issued by State Forests (February 2000) to offer a broader range of products including carbon, salinity, biomass, land rehabilitation and wood.

State Forests also intends offering a carbon accounting and carbon pooling service.

2.3.2 Other plantation development

A range of private plantation developers are either currently establishing or considering establishing plantations in the UNE/LNE CRA regions. These include Rising Forests, August

EcoForests and East Coast Tree Farms. Both hardwood and softwood plantations are being established by private companies.

Private sector players are also taking an interest in the emerging opportunities associated with carbon.

2.3.3 Future Developments in Forestry – Carbon, Biomass and Mine Rehabilitation

Under the Kyoto Protocol (1997), Australia has agreed with other developed countries to limit its anthropogenic greenhouse emissions for the period 2008-2012, to an increase of no more than eight per cent on 1990 levels. The Kyoto Protocol recognises vegetation based sinks (afforestation and reafforestation of land since 1990) as legitimate offsets to emissions based on the fact that planted forests will store carbon in roots, leaves, branches and stems. This means that planting trees on previously cleared land will build up the pool of stored carbon (carbon sequestration). Greenhouse gas emissions from industrial, domestic and agricultural sources can be offset by planting trees to sequester an equivalent or proportional mass of carbon from the atmosphere.

In November 1998, the *Carbon Rights Legislation Amendment Act (1998)* was passed in the NSW Parliament. This Act allows State Forests and public energy utilities to own, buy or sell rights to the carbon stored in trees. It allows the registration of a carbon sequestration right over land separate from the land ownership and separate from the registration of forestry right.

Although the rules for carbon accounting are yet to be fully determined, efforts are being directed to formulating a carbon accounting standard to support market based emissions trading in the expectation that the Kyoto Protocol will be ratified. State Forests has developed a carbon accounting procedure (Lamb 1999) based on best available knowledge and data, consistent with recommendations by the Inter-governmental Panel on Climate Change (IPCC) (I.P.C.C. 1998) and the Commonwealth of Australia. The Commonwealth also has also established the Cooperative Research Centre on Greenhouse Accounting along with partners such as State Forests, to further develop the knowledge base on carbon issues.

From mid-2000, the Sydney Futures Exchange intend to offer an exchange-traded market for carbon sequestration credits for the first Kyoto Commitment Period. State Forests is developing the infrastructure with joint venture partners to generate a tradeable carbon pool of sufficient size to allow trading to commence. This is expected to provide the worlds first market price for carbon.

Carbon trading may offer the plantation grower a diversified management option, free of the traditional constraints such as distance to market, and earlier returns than is usually available under a conventional two thinning, clearfall management option. Growers may have the choice to plant non-traditional species, such as rainforest trees, or may be able to develop biodiversity programs partially funded from the carbon market. The additional return from carbon will allow plantations to be developed on non-economic areas, and improve returns generally. The benefits would be offset by the cost of additional monitoring and accounting procedures in excess those required for wood-only producers.

Bioenergy Plantation material and silvicultural residues (i.e. waste wood arising from thinning, and final harvest) can be used as an alternative fuel resource for electricity generation. Recent amendments to the *Electricity Supply Act (1995)* encourage the use of biomass, a renewable resource, as an alternative fuel resource. Market access for this material provides an economic incentive for silvicultural improvements to produce sawlogs, further enhancing the plantation investment. Short rotation plantations could also be established specifically to supply bioenergy plants. Without domestic markets for these residues, the best viable option is to export for overseas manufacturing, however the north coast lacks suitable deep water ports between Newcastle and Brisbane. Recently, a feasibility study was undertaken by State Forests to examine the potential for forest residues as a source of bioenergy electricity generation, drawing from plantations as well as sawmill waste such as sawdust and off-cuts. (Heathcote and Lamb, 1999. Heathcote et al 1999a, 1999b).

The NSW Government recently amended the *Mining Act (1992)* to allow the reafforestation of mining sites as part of the rehabilitation process. This is expected to encourage plantation development in the southern part of the LNE CRA region.

3. EXISTING PLANTATIONS AND INDUSTRY

3.1.1 Location

Map 3.a shows the location of existing plantations in Northern NSW CRA regions.

3.1.2 Hardwood plantations

State Forests of NSW manages 47 200 hectares comprising of two distinct groupings, those planted prior to 1994 and post 1994. Flooded Gum and Blackbutt dominate these plantations which are concentrated in the Mid North Coast Region of Northern NSW. The area of hardwood plantations established prior to 1994 is 5 400 hectares in the UNE and 19 000 hectares in the LNE. Most of these areas were established during the 1960s and 1970s, including about 14 000 hectares by Australian Paper Manufacturers (APM) for pulpwood and subsequently purchased by SFNSW in 1994. Table 3.B and 3.C are graphically represented in Figure 3.b and 3.c for the pre 1994 plantations. The quality of these plantations is variable with establishment being through both planting of seedlings and sowing of seed.

Since 1994, approximately 22 800 hectares of hardwood plantations have been established in the Upper and Lower North-East of NSW since 1994 (see Table 3.A and Figure 3.a) mostly as joint venture arrangements between private landowners and State Forests.

Species/site selection on the north coats has generally targeted Spotted Gum *(Corymbia variegata)* for the lower productivity sites due to its ability to thrive in poorer soils and withstand extended drought periods once established. High quality sites are often subject to greater weed competition and pest problems and Flooded Gum (*Eucalyptus grandis)* is generally preferred for its high productivity and robustness compared to other species.

Dunn's White Gum *(E. dunnii)* and Blackbutt (*E. pilularis)* are generally matched to intermediary sites, however studies of advanced age plantings on high quality sites have indicated the merits of these species for capturing higher growth rates for larger sawlog size products.

Productivity and product quality gains are being made through the genetic improvement programs, and through access to genetically improved material from overseas sources. For example, a hybrid between River Red Gum (*E. camaldulensis)* and Flooded Gum (*E. grandis)* is being trialled by State Forests to capture the early productivity performance of *E. grandis* on lower productivity sites.

Data from recent plantations (post 1994) has demonstrated the effect of better site establishment and silviculture. Plantations established in the 1960's and 1970's in the Coffs Harbour region on moderate to good sites, have been found to have an average growth rate of around 10 m³/ha.yr. The average productivity achieved from recent plantations however, has been found to exceed this rate and three productivity levels have been recognised for ranking productivity across the regions expressed as total stand growth for commercial sawlog and roundwood production:

- low productivity site: 15 m³/ha.yr
- moderate productivity: 18 m³/ha.yr
- high productivity: 22 m³/ha.yr

The highest benchmark is conservatively estimated to prevent an over-estimate of future yield, and the lowest benchmark represents a commercial limitation on the poorest quality land considered suitable for commercial timber plantation establishment.

North coast plantations were benchmarked against published and reliable data by West (1999). A global maximum mean annual increment (MAI) for unthinned eucalypt plantations was established as rising to around 44 m³/ha.yr at 8-10 years, declining to around 28 m³/ha.yr at 25 years. Using data from a recent inventory of 1760 hectares of post 1994 plantations, together with research data from the region, West observed north coast plantations were achieving rates close to the benchmark maximum. The challenge for commercial wood production is to lift the estate average to as close to the global benchmark as possible, focussing on site and species as well as silviculture.

TABLE 3.A – PLANTATIONS ESTABLISHED SINCE 1994

Year	E. pilularis	E. grandis	E. maculata	E. cloeziana	E. dunnii	E. nitens	E. laevopinea	E. camaldulensis	Spp Misc	Totals
1994	25	82	0	5	79	95	5	0	9	300
1995	138	144	222	45	139	284	0	0	29	1,000
1996	352	88	1017	4	470	28	5	0	36	2,000
1997	1270	358	1936	102	1611	154	18	27	23	5,500
1998	1070	636	2268	204	1053	31	21	30	387	5,700
1999	1042	449	427	329	751	0	0	0	2	3,000
2000	472	449	1584	40	2735	0	0	0	20	5,300
Totals	**4369**	**2205**	**7453**	**731**	**6837**	**592**	**49**	**57**	**506**	**22800**

Figure 3.a – Species Planted by Age Class

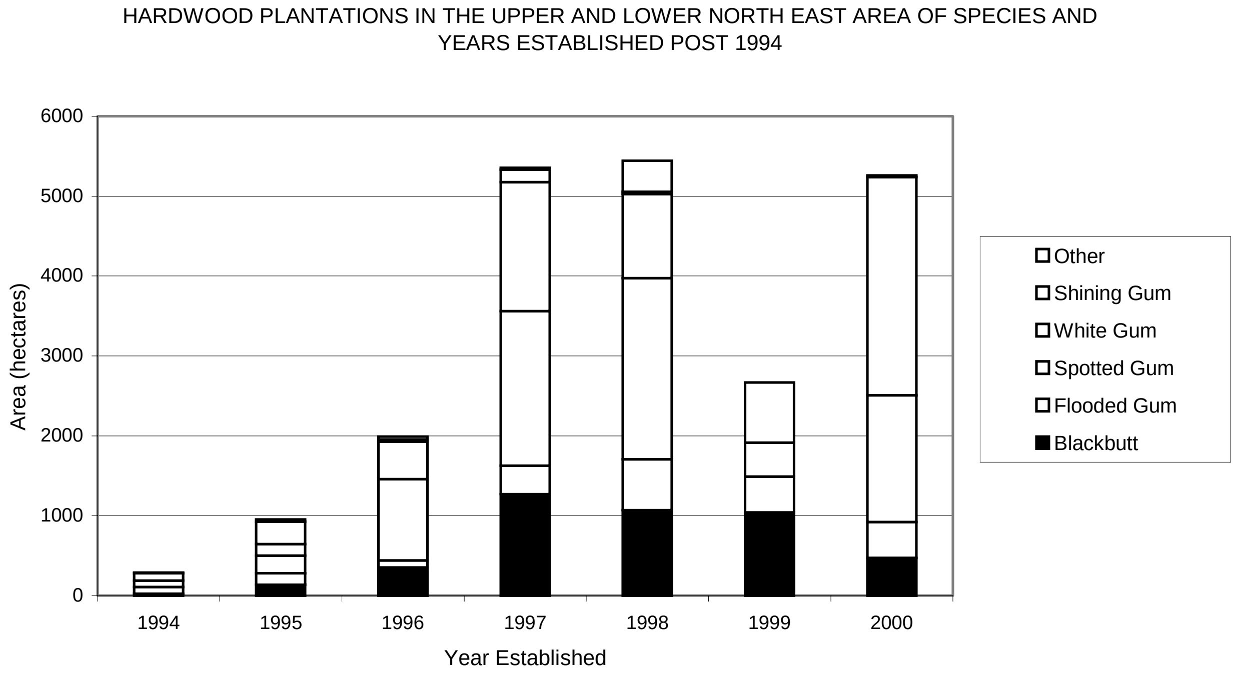


Figure 3.b - Hardwood Plantations in the Upper North-East Region

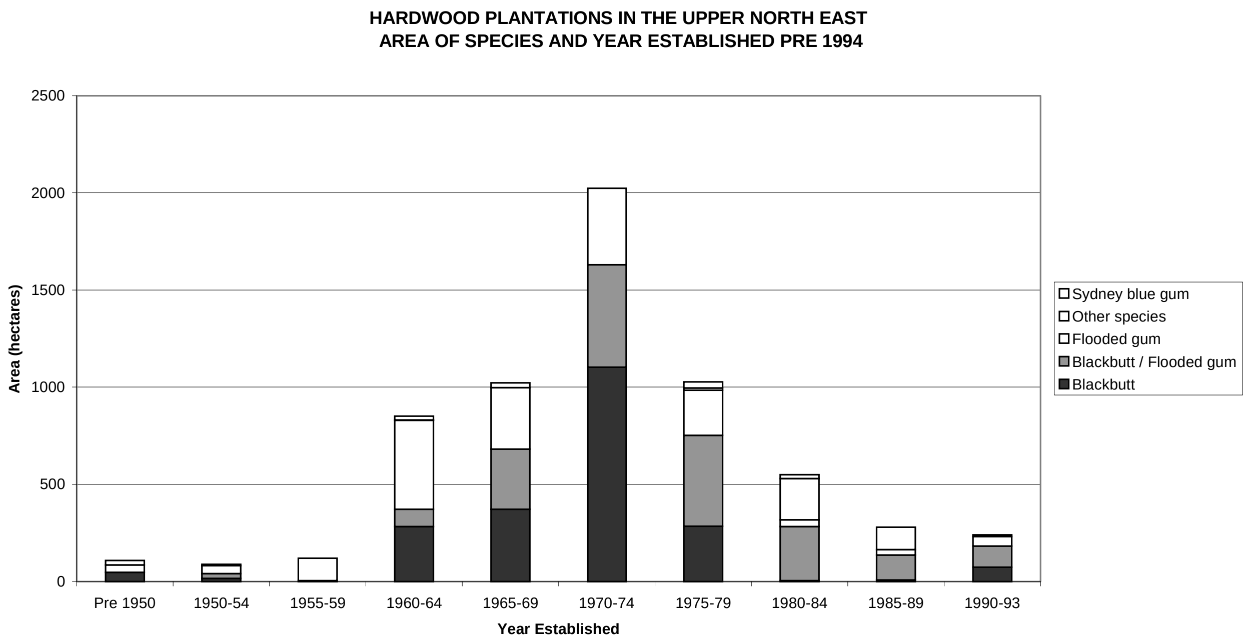


Figure 3.c - Hardwood Plantations in the Lower North-East Region

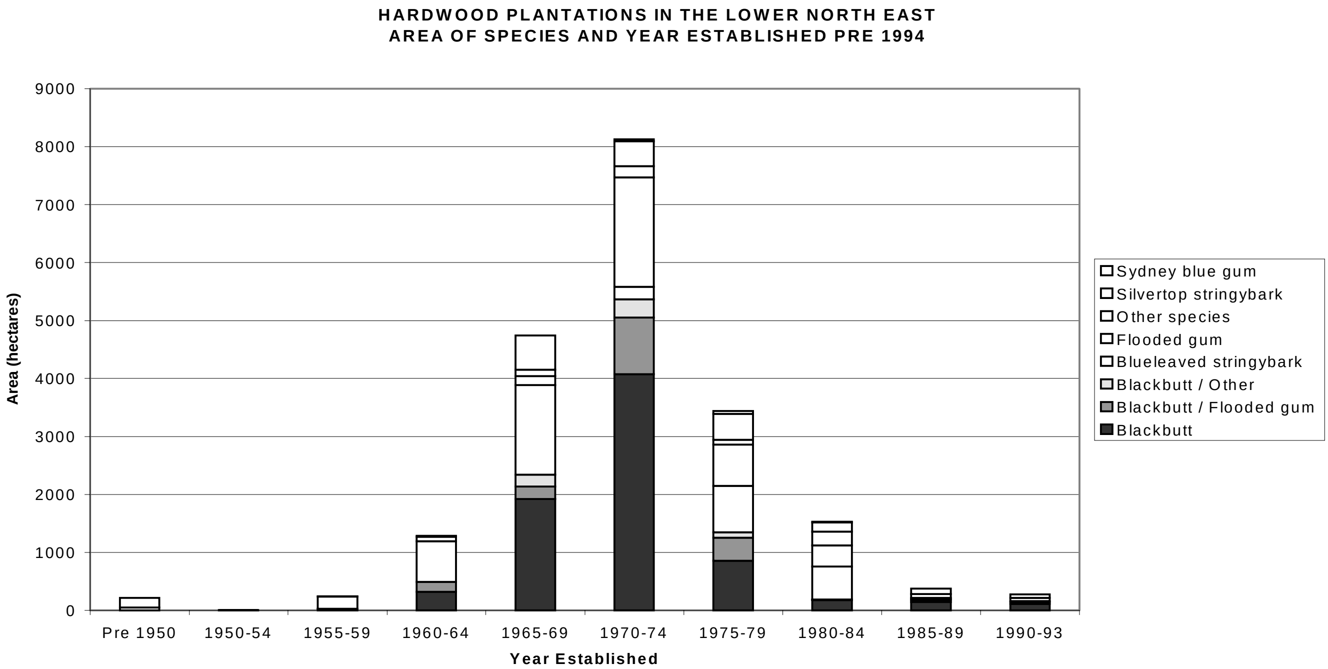


TABLE 3.B – PRE 1994 HARDWOOD PLANTATIONS IN THE UPPER NORTH EAST

YEAR	Blackbutt	Blackbutt / Flooded gum	Flooded gum	Other species	Sydney blue gum
Pre 1950	47		39	24	
1950-54	15	25	42	6	
1955-59	4		116		
1960-64	282	89	458	1	20
1965-69	372	309	317	24	
1970-74	1103	528	393		
1975-79	284	467	233	12	31
1980-84	4	279	35	211	21
1985-89	8	129	28	115	
1990-93	74	108	50	9	
Total	**2193**	**1934**	**1711**	**402**	**72**

TABLE 3.C – PRE 1994 HARDWOOD PLANTATIONS IN THE LOWER NORTH EAST

Year	Blackbutt	Blackbutt / Flooded gum	Blackbutt / Other	Blueleaved Stringybark	Flooded Gum	Other species	Silvertop Stringybark	Sydney Blue Gum
Pre 1950					49	169		
1950-54	2							
1955-59	23	7			209	2		
1960-64	317	174			702	78		18
1965-69	1926	212	208		1545	151	111	592
1970-74	4077	973	314	218	1893	190	428	36
1975-79	859	395	90	806	712	84	443	52
1980-84	178	7	1	572	363	238	159	11
1985-89	144	32	20	19	69	94		
1990-93	110	35	14		54	63		
Total	**7636**	**1835**	**647**	**1615**	**5596**	**1069**	**1141**	**7091**

Yield

The hardwood timber industry is in a transition from mature native forests to native forest regrowth and plantation grown hardwood timbers. In 1998-99 approximately 60 000m^3 of pre-1994 hardwood plantation sawlogs, veneer, poles and other products was processed by thirty-five mills across the region. This is expected to rise to 120 000 m^3/year by the period 2010-2020. An additional 80 000 m^3 of plantation residues were exported via Newcastle and Brisbane.

For some time, the volumes of small roundwood thinnings available from pre-1994 plantations have exceeded the markets for small roundwood such as pulpwood. This has resulted in overdue thinning of plantations and decline in stand quality. Thinning plantations provide mainly veneer logs, pulpwood and some sawlogs.

3.1.3 Softwood plantations

UPPER NORTH EAST

Softwood plantations total around half of the hardwood plantations at around 23 000 hectares in the Upper and Lower North-East regions. This softwood resource is dominated by Slash pine (*Pinus elliottii*) and Radiata pine (*P. radiata*), with small areas of Hoop pine (*Araucaria cunninghamii*) and Bunya pine (*A. bidwillii*).

TABLE 3.D – SOFTWOOD PLANTATION AREA IN UPPER NORTH EAST CRA REGION

Plantation Zones	Species by hectares				
	Hoop	Bunya	Slash	Radiata	**Total**
Urbenville	700	100	2000	100	**2,900**
Casino	500	0	5500	0	**6,000**
Barcoongere	0	0	1000	0	**1,000**
Clouds / Brooklana	50	10	1000	0	**1,060**
Glen Innes / Inverell	0	0	100	2000	**2,100**
Total	**1,250**	**110**	**9,600**	**2,100**	**13,060**

Yield

The plantation resource has been reviewed and a yield of 170 000 m^3/year of sawlogs and veneer logs has been determined for the ten year period as being sustainable from 1998/99. In addition, about 10 000 m^3/year of pulpwood is expected to be produced. This yield is based on the assumption that at least 5 000 hectares of new plantation will be established in the same ten year period as well as re-establishment of clearfell areas as plantation. Barcoongere plantation will not be re-established as a softwood plantation.

Softwood Timber Industry

The softwood timber industry in the Upper North East is comprised of two veneer mills and four sawmills. One of the veneer mills, Big River Timbers, uses both softwood and hardwood timber. Details of the companies are :

TABLE 3.E - SOFTWOOD TIMBER COMPANIES IN THE UPPER NORTH EAST :

Company	Location	Product
Norply	Kyogle	Veneer
Big River Timbers	Grafton	Veneer
Mesray	Wyan via Casino	Sawlog
Collenden	Lowanna via Coffs Harbour	Sawlog
Corrective Services	Glen Innes	Sawlog
Bulmer and Smith	Casino	Sawlog

These companies in total are purchasing the available yield under wood supply agreements.

An additional volume of softwood timber (approximately 8 000 m^3/year) may be supplied from the Lower North East plantations to these customers.

LOWER NORTH EAST

Resource

Softwood plantations were trialled in the Armidale and Nundle areas from the early 1920's, but the main plantation area was established from 1967 in the Nundle area. About 10 000 hectares of mainly Radiata pine currently exist.

Yield

Assessments were carried out prior to 1996, which indicated that about 80 000 m^3 of sawlog and 80 000 m^3 of pulpwood were available for a ten-year period. After that period, a similar total volume would continue to be available but the proportion of sawlog would increase.

Softwood Timber Industry

State Forests may allocate softwood timber from the Lower North East region to the softwood industry in the Upper North East region.

State Forests is actively seeking markets for this resource at present.

Map 3.a – Existing Plantations

4. DATA REVIEW

4.1 PURPOSE

A data review was undertaken to ensure that all available information was considered in 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.

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 analysis undertaken. This information was used as a reference source for the project. It should be noted that any 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 Northern NSW CRA regions. The studies are examined for: the data used, the analysis undertaken, methodology applied and the overall limitations of the studies, in terms of what this plantation project aims to achieve, and are discussed below.

4.2.1 Review of Booth and Jovanovic (1991)

This was a broad-scale 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 Northern NSW Forestry, North Coast Forest and Plantation Resource Study - 1994

This study was produced for the Northern Rivers Regional Development Board. It provides an assessment of private native forest resource and the potential for plantation establishment on cleared private land. The assessment of plantation land availability was based upon a landholder survey and SFNSW joint venture agreements/expressions of interest.

The study area

The region covered is effectively from Port Macquarie through to the Queensland border and west through to Armidale and Tenterfield.

Methodology applied

The study relied upon two methods for establishing the potential area of plantations. The first method was based upon a survey of 491 landholders that canvassed the potential for plantation establishment in the study area. The second method relied upon SFNSW expressions of interest from landholders within the study area wishing to establish joint venture plantations.

Limitations

The study provides an indication of potential area available and interest from the farming community to establish plantations. It does not attempt to spatially determine which areas are most capable and suitable. While this shows an approximate area available, there is no assessment of whether this land is capable and suitable in terms of the soil types, proximity to markets, rainfall etc.

4.2.3 Review of Northern NSW Forestry, Mid-North Coast Forest and Plantation Resource Study - 1996

This study assesses private native forests and plantation resources within the Mid-North Coast region. The study uses SFNSW GIS analysis and results of landowner surveys to obtain an estimate of available land for plantation establishment.

The study area

The region covered is the Hastings, Greater Taree, Gloucester, Dungog, and Great Lakes Shires of the Mid-North Coast.

Methodology applied

The study used SFNSW data and GIS mapping capability as available at June 1996. The initial mapping of potentially suitable plantation sites considered areas that were mapped as:

- > 900 mm annual rainfall;
- cleared private land;
- non-prime horticultural/agricultural land;

- sites < 18 degrees slope; and
- suitable soils.

In addition to using the information available from the SFNSW data, a survey of 500 landowners within the study area canvassed the level of interest in possible plantation establishment.

Limitations

The study provides an indication of potential area available and interest from the farming community to establish plantations. It uses this analysis to obtain estimates of areas potentially suitable for plantation establishment in NSW. It also provides estimates of internal rate of return given predicted growth rates, cost of land, and establishment costs. The study does not provide analysis for specific species or use the full set of criteria used within the CRA study.

4.2.4 Review of the SFNSW, GIS analysis of land potentially suitable for eucalypt plantation-North Coast of NSW - 1996

This study, used as a basis, the mid-North Coast forest assessment described in 4.2.3 and applied it to the 1994 study area. It looks at both capability and suitability factors but does not include an economic analysis.

The study area

North Coast NSW

Methodology applied

The study used SFNSW data and GIS mapping capability with potentially suitable plantation sites mapped as:

- > 900 mm annual rainfall;
- cleared private land;
- non-prime horticultural/agricultural land;
- sites < 18 degrees slope; and
- suitable soils.

Limitations

This study is the closest to the aims of the CRA study in terms of the area covered and capability and suitability envelopes used. It provides a very brief discussion of the methodology and does not explore individual species or provide any economic analysis. The methodology in the report provides only an initial indication of generalised plantation potential.

4.2.5 Review of ABARE WAPIS study 1999

The ABARE study *Forest Plantations on Cleared Agricultural Land in Australia* (Burns, Walker and Hansard 1999) represents the first study in Australia that considers plantation suitability all of Australia based on economic and biological factors relating to growing, transporting, processing and marketing plantation timber. The study developed an economic model, REAP (Regional Economic Analysis of Plantations), to assess the factors affecting economic plantation suitability in Australia.

The study area

The study covered all the fourteen NPI regions within Australia. This includes the northern NSW CRA regions, which are included in the North Coast and Northern Tablelands NPI region.

Methodology applied

The REAP analysis examined the potential returns to plantation investments (expressed as net present value) and compared these to the estimated value of land currently used for agricultural enterprises. The study focussed on broad-scale plantation development, and hence did not estimate the potential for agroforestry oriented investments.

The potential plantation land values were calculated based on timber stumpage prices, yields, and existing processing infrastructure supplied from Margules Groome Pöyry, potential industry development options derived in conjunction with State Forests of NSW, land productivity and availability supplied by BRS, and agricultural land value estimates derived from ABARE's farm survey data (ABARE,1999).

Limitations

The report detailed several assumptions and issues involved with the analysis of plantation potential in Australia, including:

- The model examined the potential development of world-scale sawmills and pulpmills in each region, and assumed that investments in these facilities can be of any size, up to a maximum size for each processing type, with constant per unit variable and capital costs. In reality such investments in processing capacity are not totally divisible (as assumed in the study). Therefore this approach may overstate the potential for industry (and hence plantation) development in some cases.
- Farmers' estimates of the value of agricultural land were used as proxies for the values from existing agricultural activities (excluding plantations) that compete against plantations. Where significant personal or social amenity values exist, this may understate the potential for plantation development.
- Only the commercial timber (and, to a limited extent, carbon) returns to plantations are covered in the report. In some situations plantations on agricultural land can provide additional environmental benefits, which may increase the potential for plantation development in regions where environmental (land degradation) issues are prevalent.
- The productivity information supplied by BRS was derived by ranking the cleared land by rainfall isohyets, independently assigning silvicultural regimes and yield tables for *E. grandis, E. pilularis, Corymbia variegata* and *Pinus radiata*. The CRA study uses a more comprehensive inclusion of other environmental variables including soil waterlogging and elevation.

Further discussion of the assumptions relating to the data and modelling framework are contained in the report.

4.3 DATA REQUIRED FOR THE PROJECT

Appendix 2 and chapters 5 and 6 detail the data required to undertake this project, the data that are currently available, any data gaps/limitations in the existing data and actions required to address these gaps/limitations.

4.4 CONCLUSION - DATA OVERVIEW

Land capability and suitability works have previously been undertaken in the Northern 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.

This project enables consistent analysis to be undertaken throughout the U/LNE CRA region and covers areas of capability, suitability and economic analysis which has not been undertaken in any previous study.

5. PLANTATION CAPABILITY

5.1 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, that 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 (e.g. 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 (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 (CRA/RFA Steering Committee, 1998).

5.1.1 *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 time steps, 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 hectare
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 model 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, and actual productivity well at a local scale. 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 local scale study based on finer data are necessary to refine predictions.

5.1.2 *Spatial inputs : Climate and soil data*

The model requires long term mean monthly climate data and best available soil data (refer to Tables 5.A and 5.B). Appendix 3 provides 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. (McMahon et al, 1997)
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 0.5 Very Low Fertility 2 0.7 3 0.7 4 0.9 5 0.9 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 Upper and Lower North East regions using the boundaries received from State Forests in late August, 1999.

Model outputs cover the area common to all input datasets. The climate data are generated according to the extent of the AUSLIG 9 second digital elevation model which extends from the coast inland to UTM Zone 56, 350665 (i.e. truncated to the west of this easting). Soil mapping is complete for the Lower North East, but in the Upper North East no data are available for most of the region west of UTM Zone 56, 378320.

5.1.3 *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); and
- species specific calibration parameters, particularly allometrics which determine partitioning of biomass to root, stem and leaf.

5.2 METHODOLOGY

5.2.1 *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). Appendix 4 lists the requirements for the species analysed in this report as documented by Booth and Jovanovic (1991).

Joe Landsberg, one of the authors of the 3PG model, performed the calibration for each species using the regional scale spatial input data and State Forests site data at selected locations. Six to ten points were selected from State Forests plot locations for each species. Site data reflects local scale variability which is unlikely to be well represented in coarse scale input surfaces. The data are from existing commercial plantations in the medium productivity range. The calibration exercise aims to predict the site data at these points.

Hardwood calibration points for *E. grandis, E. pilularis, Corymbia* (*maculata* and *variegata*) were selected to ensure a good spread of :

- Average Site Index (height (m) at Age 20) i.e. average of SI at all plots located near x,y coordinates;

- Volume as predicted by the model PYP (Plantation Yield Prediction Model, West 1998 - see Appendix 6) as field measured data were not available;
- climate and soil data;
- spatial locations where possible; and
- older sites where relevant.

P. elliottii calibration points were selected to:

- reflect the range of young sites (age less than 30 on the measurement date during the 1990s), as old stands are biased towards poor performance & do not reflect the potential of new plantings, based on new hybrids and closer management (pers. comm. Mike Welch, SF NSW)
- reflect the range of measured productivity (DBH mm/year for *P. elliottii* ranges from 3.3 to 17.9, mean 10.1)
- encompass the environmental envelope from the three key regimes of Coast, Mountain, Western Slopes, as far as the above constraints allowed.

Araucaria cunninghamii calibration points were selected to :

- span the age range (the age range of the data were 15 to 62 years with the calibration points ranging from 17 to 54)
- span the measured range of productivity (DBH mm/year ranges from 4 to 14.9 with the calibration points ranging from 5.7 to 14.9)
- encompass the environmental envelope from the three key regimes of Coast, Mountain, Western Slopes

The plot data available for calibration was limited for some species. There were about twenty *Corymbia maculata* and *variegata* plots spread over six locations identified by coordinates, so only six sites could be used in calibration with an average Site Index range of 25.4 to 30.3m.

5.2.2 Model runs and refinement

Model runs were performed for all three hardwoods and both softwoods. 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.

Model outputs were provided to expert validators (State Forests 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.

Hardwoods

The hardwood surfaces were compared against Thematic Mapper satellite imagery to assess whether interpretations of the land cover and land uses visible in the imagery coincided with areas of differing predicted productivity e.g. high productivity areas are often cleared for high value land uses, low productivity areas include ridge-tops.

Validation was undertaken at several points representing a range of climate-soil combinations, including existing plantations and areas known to SFNSW. These sites were assessed as part of the detailed field sampling program to develop a regional soil manual for establishing hardwood species (J. Grant pers. comm.). The model outputs were generally found to be over-predicting productivity on coastal sites, and the western part of the CRA region. The western side of the region is considered commercially unproductive due to extremes of climate e.g. frosting or drought. The over-prediction on coastal areas was thought to be largely driven by the coarse soils data which overlooked localised areas of lower fertility and impeded drainage caused by clay pans found under moderately deep sands. These issues are addressed below in the section on Thresholding.

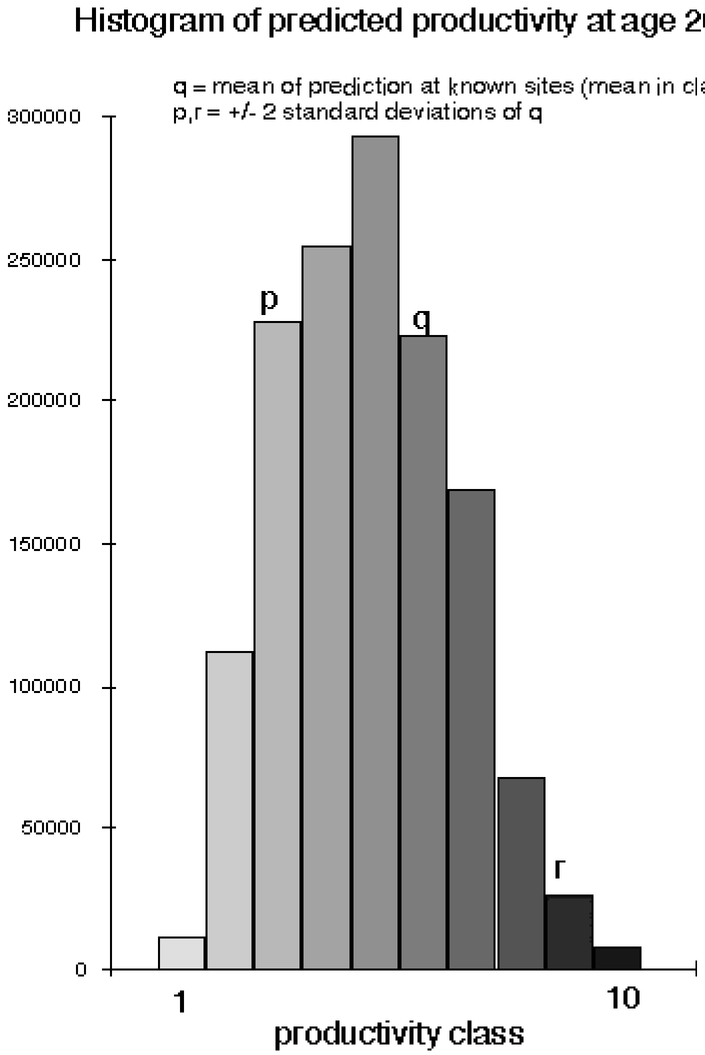
The first run of the model for each of the hardwoods produced results which the SFNSW hardwood validators thought were a good representation of regional trends in relative productivity. However as discussed below, there was insufficient data to assess the reliability of the model projections for each species across the entire landscape, and a single hardwood surface was selected to represent the relative productivity for all three species.

Predicted results compared with existing *Eucalyptus pilularis* plantations

The histogram in Figure 5.a shows how the area in the Northern CRA regions are distributed according to predicted standing volume. The histogram’s Y axis shows the count of 250m cells each representing 6.25 hectares; the X axis shows the classified stem standing volume at age 20. Data on *E. pilularis* plantations, provided for purposes of model validation by State Forests, is located in areas with predicted productivity ranging from class 3 (low-medium) to class 9 (high).

Significant variation in site data volumes was found within close proximity of each other. There was not commensurate variability in the regional scale input surfaces to enable prediction of such local scale yield variability. This highlights the need 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 Hardwoods (*E. Pilularis* Site Data)



Softwoods

The initial predictions for the softwoods showed incorrect trends in regional relative productivity, with coastal locations showing relatively much higher productivity than expected for species more adapted to cooler climates. Input data at four existing plantations was assessed to determine whether climate or soil information reflected the expected trend of lower productivity at Barcoongere and Whiporie plantations and higher productivity at Clouds Creek and Yabbra. At all four locations, fertility, radiation and wetness (rainfall and soil water holding capacity) are similar or vary without trend. Temperature surfaces reflected the expected trend. Values at the better sites (lower minimum temperatures and lower maximum temperatures) were used to set new temperature function constraints.

The temperature parameters were adjusted and Table 5.C shows the values used in degrees C. The following definitions apply:

- Minimum temperature is the average monthly temperature (long term average of monthly minimums and maximums) below which the species is not expected to grow in the region;

- Maximum temperature is the average monthly temperature (long term average) ABOVE which the species is not expected to grow in the region; and
- Optimum temperature is the average monthly temperature (long term average) at which maximum productivity occurs.

TABLE 5.C - TEMPERATURE PARAMETERS FOR SOFTWOODS

Model Run for softwoods	Minimum Temperature	Optimum Temperature	Maximum Temperature
Initial	5	22	35
Final	0	18	27

By using the adjusted parameters, the resulting predictions for Hoop and Slash pine were a better representation of relative productivity.

5.2.3 *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 makes it easier to determine what that threshold is; and
- **provide expected/estimated quantitative ranges (e.g. MAI) or indicative values and yield tables** for each productivity class. Yield tables (for all 3 productivity classes including thinning regime and expected yields for each species) are essential for economic modelling.

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

Thresholding

1. 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 means 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 species (except *Corymbia* for which no ruleset existed) was provided to the validators. In all cases the validators rejected these because they had plantations growing in the masked out areas.

Other means exist to identify and exclude areas that are thought to be unable to support commercial plantations:

- One means of defining a biophysical capability threshold is using a value from the 3PG-SPATIAL productivity output; and
- Existing planting practices use climatic or other rules to exclude areas that are likely to be at risk from environmental conditions.

Rainfall and minimum temperature criteria were selected to produce a single mask to threshold all species. Threshold values were iteratively determined based on what the validators thought was appropriate and reviewing the spatial implications of the ruleset against known plantations. Those areas that did not meet the minimum environmental thresholds listed in Table 5.D were masked out.

TABLE 5.D - MINIMUM ENVIRONMENTAL THRESHOLDS

Variable	Minimum value of variable
mean minimum temperature of coldest month	0 ^{0}C
minimum total annual rainfall	900 mm

The resultant mask was approved with the following provisos :

Softwoods

Hoop & Slash pines are known to grow well in Tooloom State Forest south-west of Woodenbong which is very close to the mask. The Dorrigo plateau and associated escarpment is known to grow good natural stands of Hoop pine even though the mask appears to exclude some of this area. It is likely that micro-climatic factors have an effect. The species probably regenerates naturally under a cover crop and certain aspects and topographic positions may be suitable for growing Hoop pine in plantation although this can’t be modelled at the regional scale. The Northern Tablelands have quite severe winter temperatures and are unsuitable for growing the two species although it is known that *Pinus radiata* performs quite well around Walcha, Armidale and Glen Innes. Other pine species suited to drier conditions may well grow successfully in the western part of the Region.

Hardwoods

In some cases (for particular hardwood species at particular locations), the mask allows more land in the high altitude tablelands than would normally be considered, thus a large area will appear in the low productivity class when it may in fact be incapable. In other cases, such as the Dorrigo plateau, high altitude areas have been masked out even though they have been proven capable for *E. grandis* growth.

2. Waterlogging

There were areas of known impeded drainage e.g. near Ballina and Grafton. 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.

To address this, slope and soil-derived drainage data were used to develop a waterlogging mask to exclude areas that are both poorly drained and flat. However validators thought the resulting mask was too extensive e.g. it masked areas of existing *P. elliottii* plantations. Although the productivity surfaces have not been spatially masked, waterlogging is likely to affect both the area of productive land and the degree of productivity.

3. Poor fertility soil

The fertility data input to the model was classified into the two extreme classes of high and low with the remaining soil classes merged into one medium fertility class. This was to distinguish areas where fertility was likely to be an important driver of productivity and to ensure that fertility did not unduly affect the model where it was thought climate data might be more reliable as the primary driver of productivity. The validators thought that too much of the region was left in this medium fertility class and believed that productivity in some locations (particularly in the coastal area which, due to its mild coastal temperatures and relatively high and reliable rainfall, had predictions of high productivity) was unduly affected by a medium classification rather than a poor classification.

Due to the late stage in the validation process when this was discovered, and the limited area thought to be affected, the model was not re-run with revised soil data. Instead, the coastal sandstone units in the soil data along the coast east of Grafton, between Woolgoolga and Yamba (where the Barcoongere Slash pine plantations are located) were selected and the modelled productivity for the hardwoods and both softwoods were changed from their original value to the low productivity class.

Classification

Once the above thresholds were agreed, the predicted productivity surfaces 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.

Softwoods

In the case of *Pinus elliottii*, existing plantations tended to fall fairly neatly into three productivity classes typified by Barcoongere for low, Banyabba – Whiporie for medium and Yabbra for high. Yield tables were selected from existing typical stands in each of these categories.

All existing Hoop pine plantations are located on relatively fertile sites of high rainfall. The model outputs reflect this fairly well. In the absence of existing plantations at lower productivity locations, it was not possible to validate the spatial thresholds which were selected to delineate the low and medium classes, nevertheless, they are thought to be indicative.

Hardwoods

Experience in existing plantations shows that the three species *Eucalyptus grandis, E. pilularis* and *Corymbia variegata* tend to perform differently on different sites. For example, *E. grandis* is better able to capture the productivity of high quality sites, than the other two species. However, it does not perform well on moderate quality sites, and in current planting practice, *E. pilularis* is preferred as a very reliable moderate site quality species. *Corymbia variegata* is used on low productivity sites due to its hardiness and good form.

Consequently (and due to the lack of data to assess the reliability of the model projections for each species across the entire landscape), a single hardwood surface was selected to represent the relative productivity for all three species. *E. pilularis* was used as this default layer as its growth trajectory is generally located between *E. grandis* and *Corymbia variegata*. Species' performance was then reintroduced to the analysis for wood yield forecasting by attributing silvicultural tables for the three species by productivity class as detailed below.

Quantitative ranges for productivity classes

Productivity intervals were attributed to the 3PG-SPATIAL outputs based on SFNSW corporate commercial experience. The expected MAI at age 20 for each species is shown in Table 5.E.

TABLE 5.E – EXPECTED MAI AT AGE 20

Species	High Productivity (m^3/hectare)	Medium Productivity (m^3/hectare)	Low Productivity (m^3/hectare)
Hardwoods	>20 (*E. grandis*)	15-20 (*E. pilularis*)	<15 (*Corymbia*)
P. elliottii	>17	12-17	< 12
Araucaria cunninghamii	>20	Not expected to grow	Not expected to grow

Individual Problem Areas

A major constraint in validating any capability prediction is the lack of empirical data for species' performance on new sites across the entire region. Areas where the prediction of productivity is known or thought to be wrong are discussed below.

General

While soil-related issues such as waterlogging and poor fertility have been identified in zones as the likely causes of prediction inaccuracy, there appears to be a common trend for all species of over-prediction along the coast. In the case of softwoods, this was recognised and parameters relating to species temperature response were modified, resulting in this trend being corrected to some degree. Experience in using the model in the Southern CRA region confirms that temperature functions are important drivers of relative productivity across climate gradients.

Softwoods

The validation process for both *Pinus elliottii* and *Araucaria cunninghamii* concentrated around existing production scale plantations which were all in the Upper North East region. These plantations included:

- Banyabba – Whiporie between Grafton and Casino
- Mt Pikapene south-west of Casino
- Mebbin between Murwillumbah and Kyogle
- various locations around the Kyogle – Urbenville area
- Barcoongere north of Woolgoolga
- Brooklana and Clouds Creek in the Dorrigo area.

Of particular note was the fact that the model predicted high site productivity for both species in the coastal zone north of Woolgoolga despite the fact that Slash pine plantations at Barcoongere State forest have performed very poorly. To address this problem, some local amendments were made to soil fertility thus reducing the modelled productivity in the area. It was not possible, however, to subject areas without existing pine plantations to the same level of scrutiny.

The area to the east of the Richmond Range remains a problem in that it is actually thought to be of medium productivity rather than low and is one of the areas most likely to be suitable for a reasonable expansion of the current plantation estate.

The Lower North East region is not well represented with softwood plantations. Consequently, no empirical data are available to confirm the predictions and the model output should be treated with caution in that region.

Previous plantations of *Pinus elliottii* north west of Bulahdelah i.e. tablelands and west of escarpment have performed poorly. Similarly in the Wyong management plan, *Pinus elliottii* is recorded as growing very poorly, however it may be that it was a poor site – it was recorded as an attempt to convert "dry hardwood" types (i.e. generally shallow or low fertility soils, often on westerly or northerly aspects) to something more productive (pers.comm. D. Cromarty, SFNSW).

Hoop pine plantations have been established by State Forests, over a number of decades, on sites with high fertility and high rainfall (generally ex-rainforest sites) within various State forests in the Upper North East. These have proven to be high site index sites and the plantations have been quite productive. However several factors have mitigated against further expansion of this program in later years. These factors include:

- High establishment costs including early weed control due to slow initial growth;
- Market substitution for premium-priced softwood (butter boxes, joinery timbers etc.);
- Limited availability of suitable sites (existing rainforest or highly improved agricultural land); and
- Superior economics for Slash pines on low to medium site index sites, particularly with improved genetic material for these species.

For these reasons, Slash pines have been the focus of softwood plantation expansion in recent decades and the market has developed on this resource base. Current economic analysis indicate that Hoop pine is not worth considering on sites of low to moderate fertility and rainfall when compared to Slash pines and hence it has not been considered further on such sites in this study.

Hardwoods

The same problem (described above) of over prediction in the coastal zone north of Woolgoolga occurred for hardwoods, and was partially addressed by identifying areas of poor soil fertility and modifying the prediction accordingly. Nevertheless, just west of this zone, south east of Grafton, remains an area of predicted high productivity which is thought to be of moderate productivity. In addition, productivity levels around Woodenbong would be expected to be higher than those demonstrated in the study.

5.3 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.

From the information above, one needs to bear in mind 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 an operational scale, as limitations in the information content of regional input surfaces cannot be resolved.

5.3.1 Hardwoods

Map 5.a and 5.b show the location of the areas capable of growing:

- *E. grandis* ie high productivity
- *E. pilularis* ie medium productivity
- *Corymbia (maculata* and *variegata)* ie low productivity

across all tenures and on cleared private land.

Nodes of potentially high productivity occur in the north eastern part of UNE, around Nambucca Heads and Coffs Harbour and north west and south west of Port Macquarie. Contiguous areas of potentially medium productivity occur around Murwillumbah, south west of Grafton, north west of Kempsey along the Macleay River and west of Gosford and Newcastle. Large areas of potentially low productivity exist west of the Richmond Range in the UNE.

Map 5.a – Predicted Productivity of Hardwoods across all Tenures

Map 5.b – Predicted Productivity of Hardwoods on Cleared Private Land

5.3.2 P. elliottii

Map 5.c and 5.d show the location of the areas capable of growing *P. elliottii* across all tenures and on cleared private land. Nodes of potentially high productivity occur in the northern part of UNE, around Nambucca Heads and Coffs Harbour, north west and south west of Port Macquarie, west from Bulahdelah and west from Gosford. Contiguous areas of potentially medium productivity occur to the east of Tenterfield and Glenn Innes. The areas of potentially low productivity are restricted to the immediate east and west of the Richmond Range in the UNE and to the coast north of Coffs Harbour and south of Ballina.

Map 5.c – Predicted Productivity of *P. elliottii* across all Tenures

Map 5.d – Predicted Productivity of *Pinus elliotti* on Cleared Private Land

5.3.3 Araucaria cunninghamii

Map 5.e and 5.f show the location of the areas capable of growing *Araucaria cunninghamii* across all tenures and on cleared private land.

Nodes of potentially high productivity occur in the north eastern tip of UNE, around Nambucca Heads and Coffs Harbour and north west and south west of Port Macquarie. Contiguous areas of potentially medium productivity occur to the east of Tenterfield and Glenn Innes, south west of Grafton, north west of Kempsey along the Macleay River, east of Gloucester and west of Gosford and Newcastle. The areas of potentially low productivity are largely restricted to immediately east and west of the Richmond Range in the UNE and to the coast north of Coffs Harbour and south of Ballina.

Map 5.E – Predicted Productivity of *Araucaria cunninghamii* across all Tenures

Map 5.f – Predicted Productivity of Hoop pine on Cleared Private Land

5.4 CONCLUSIONS

While the 3PG model and 3PG-SPATIAL have been applied successfully at regional and local scales respectively, this study is the first to use 3PG-SPATIAL :

- over such a large area;
- at regional scale; and
- using external expert validation.

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. An operational scale 3PG-SPATIAL analysis can be expected to show topographic variation in yield and to model known field data. A number of procedural improvements were identified and employed where possible in the Southern CRA capability analysis (Table 5.F).

TABLE 5.F – PROCEDURAL IMPROVEMENTS

Issue	**Suggested Improvements in future regional scale studies**
Most of the anomalies identified in the productivity predictions could be traced to the input soil classifications or the way the model constrained or sustained growth based on parameters relating to species response.	Significant improvement of the model predictions may be achieved by : • preliminary validation of soil classifications input to the model to ensure they reflect relative regional variability correctly • using knowledge of the original native vegetation or at known sites to develop appropriate species temperature response functions
Due to initial time constraints : • parameterisation was limited to a single variable file per species for the entire region eg rather than allometrics for low/high productivity per spp and/or temperature constraints relevant per bioregion. • a single mask was used for all species.	• Environmental data (climate and soil) input to the model should still ensure reliable relative productivity predictions. • Different methods can be employed and different masks produced for each species. • Use of species specific masks and parameters.
Calibration and validation data were limited to existing commercial plantations (limited productivity range and spatial extent) and in some cases yields were modelled from site index rather than based on actual measurements.	Pre-existing native vegetation data could provide a means of refining parameterisation which is representative of a wider environmental envelope, as well as determining appropriate thresholds.
Verification of modelled results by expert validators was slow and the number of iterations less than desirable as a result.	A number of model runs and higher level of internal BRS validation ensure that the model outputs are at a more refined stage prior to iterations with expert validators.
Expert validation of outputs without spatial software i.e. using hardcopy print-outs makes it very difficult to locate areas correctly.	Once validators agree that the 3PG-SPATIAL surfaces represent relative regional productivity, thresholding and classification is most easily performed collaboratively using spatial software.
The study concentrated on the most productive Coastal region and excluded lower rainfall Tablelands. The Tablelands region could quite possibly be suitable for *Pinus radiata* and some hardwood species such as *E. nitens, E. viminalis* and *E. dunnii* plantations.	Consider a different species regime for Tablelands region i.e. *E. nitens, P. radiata, E. viminalis* or *E. dunnii.*

6. PLANTATION SUITABILITY

6.1 THE CONCEPT OF PLANTATION 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 examines external factors that prevent 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, but for a number of themes, no or insufficient data means that the analysis is limited to a non-spatial estimate. The data used for the analysis is presented below, and 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 meant 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 is the one that was current on 30 September 1999 (version 5), provided by the Resource and Conservation Division (RACD). This layer is 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 categories are outlined in Table 6.A, which were then classed on their availability for plantation agriculture and is graphically shown in Map 6.a.

TABLE 6.A - LAND USE BY SUITABILITY FOR PLANTATIONS AND AREA

Land Use	Availability	Area (hectare)
Public Land	no	2 831 000
Mixed Grazing	yes	2 340 000
Tablelands Grazing	yes	1 928 000
Grazing/Grassland	yes	1 505 000
Coastal Grazing	yes	490 000
Rural Residential	no	198 000
Mixed Cropping	yes	113 000
Extensive Cropping	yes	67 000
Horticulture	no	64 000
Urban	no	48 000
Waterbodies	no	39 000
Intensive Cropping	yes	36 000
Dairying	yes	21 000
Mining/Quarrying	no	10 000
Utilities/Other	no	6 000
No Data	no	2 000
Recreation	no	400
Intensive Animal Production	no	100
Total Area Available		**3 198 500**
Total Area Unavailable		**6 500 000**

This land use layer was compiled by BRS from the following sources:

- Land tenure – 1:25 000 scale dataset delineating 13 public land categories along with private land.
- Australian Agricultural and Grazing Industries Survey (ABARE 1996-97) land value as a generalised coverage.
- NSW Department of Land and Water Conservation (DLWC) multi-attribute mapping of land use. Mapped at 1:25 000 in the Coffs Harbour region and 1:100 000 in the Hunter region.
- Road networks – 1:250 000 scale on private land from AUSLIG's TOPO250 dataset (no impact on areas).
- Processing facilities
- Satellite imagery – Landsat Thematic mapper imagery for December, 1994
- Slope – derived from LIC 25 metre DEM.

Land tenure was used as the base masking of public versus private land. DLWC multi-attribute mapping was used to add further detail about land use in the Coffs Harbour and Hunter regions, while digitising of Landsat TM imagery with assistance from John Hindle (NSW Department of Agriculture) was used to map and validate land use in remaining areas at 1:100 000.

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

The CRAFTI (Comprehensive Regional Assessment Aerial Photographic Interpretation) layer consists of the forest/non-forest mask and non-forest special features from the CRAFTI structural vegetation dataset. 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
R	Rainforest
F	Forest
P	Existing Plantation
W	Waterbodies
Z	Coastal Complex
Y	Estuarine Complex
V	Developed Land
N	Native pioneer species
K	Rocky ground
H	Heath
B	River beds
M	Mallee
G	Native grassland
T	Power transmission lines

As CRAFTI data were not available for the Lower North East, a gauge of the impact of CRAFTI can be made by comparison with Upper North East data. This estimate cannot however be mapped on the spatial layer for the Lower North East

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 given that the focus of this study is on cleared land. 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 detected patch size across all tenures. Table 6C shows the types of landcover described by ALCC and how it is treated in this analysis.

TABLE 6.C - SUMMARY OF AGRICULTURAL LAND COVER CHANGE LANDCOVER CATEGORIES

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)

Source: Kitchin & Barson, 1998

Steep areas

Plantation establishment on very steep land is precluded due to limitations placed on commercial harvesting in relation to soil protection measures rather than limitations on tree planting itself. A limit of 30 degrees has been used previously in plantations for ground-based mechanical harvesting, (specified under the *Timber Plantations (Harvest Guarantee) Act (1995))*, however, the *Soil Conservation Act (1938)* allows for the declaration of protected lands status on slopes of greater than 18 degrees. This does not automatically preclude harvesting from these areas, however approval must currently be sought from the Director-General of the Department of Land and Water Conservation prior to harvesting. Slope limitations on commercial plantation establishment and harvesting will be further addressed under the new *Plantations and Reafforestation Act (1999).*

However, for the purpose of this study a mask of areas with slope greater than 18 degrees was used, derived from a National Parks & Wildlife compiled 25 metre DEM (originally from LIC).

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.

For example, half of a property may be available for planting, but if the available area occurs as a few large patches rather than many small patches (less than 25 hectares in size), it would be more attractive for plantation establishment. Plantation establishment may be warranted if there are sufficient sub 25 hectare patches on the other property, but this would depend on the circumstance. The patch size distribution in figure 6.a, b and c, shows the area available in contiguous ‘chunks’ regardless of title. This allows for banding together of smaller properties and removal of the properties where there is less than 25 hectares in a patch.

Figure 6.a – Patch Size Distribution of Net Plantable Areas for Hoop pine

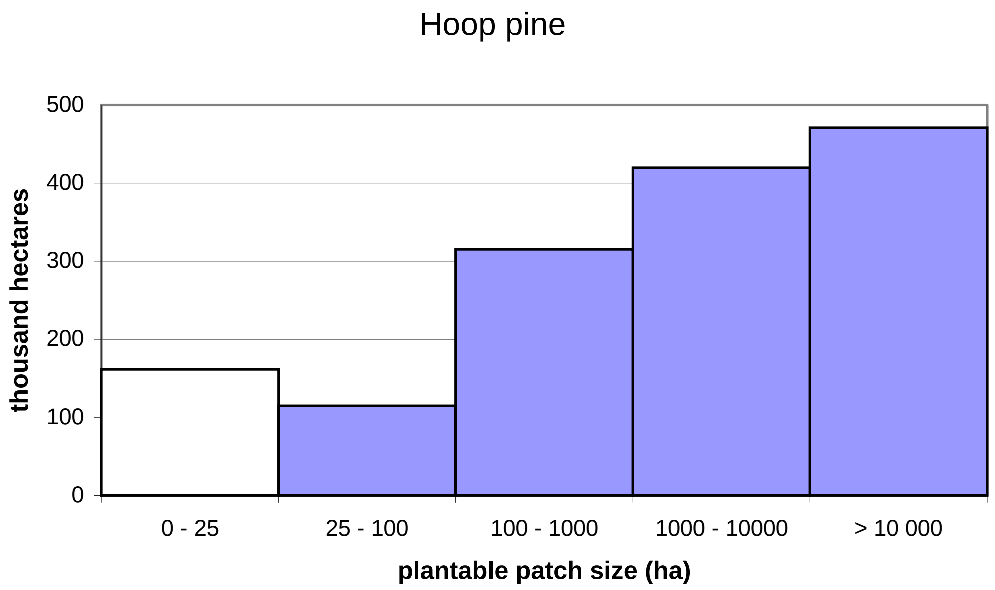


Figure 6.b - Patch Size Distribution of Net Plantable Areas for Slash pine

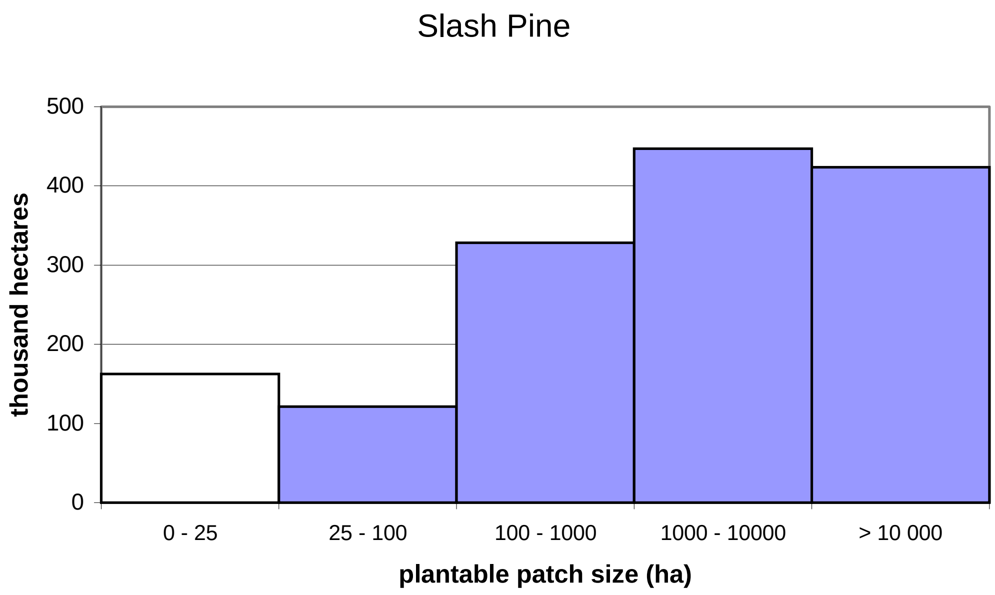
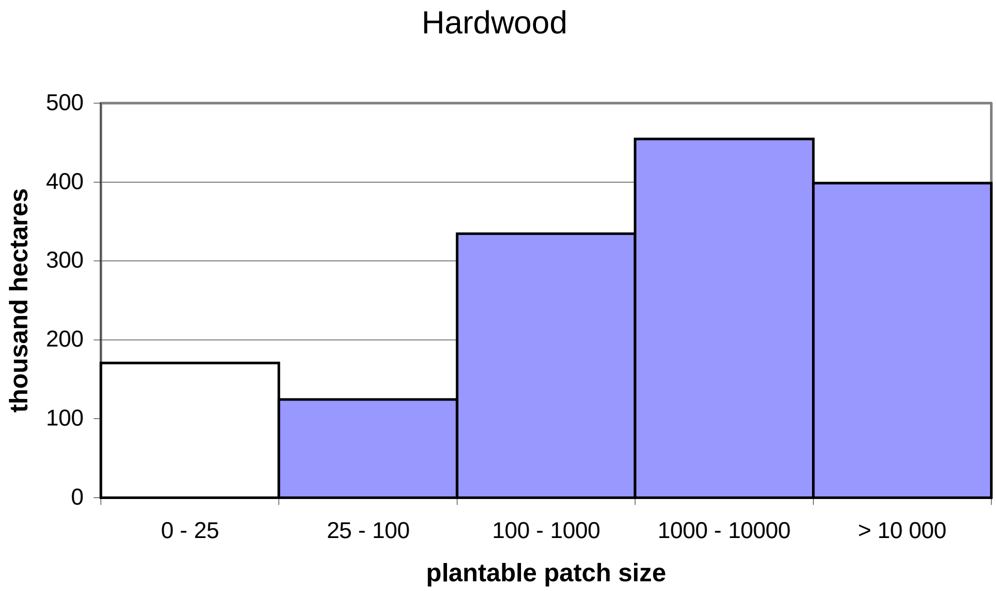


Figure 6.c - Patch Size Distribution of Net Plantable Areas for Hardwood



6.2.2 NON-SPATIAL DATA

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

- Remnant Native Vegetation (not mapped by either CRAFTI or ALCC)
- Acid Sulphate Soils (common in low-lying coastal areas)
- Environmental Exclusions (including slope, threatened species, soil erodability etc)
- Utility easements (including powerlines, pipelines, roads, infrastructure)
- Native grasslands (in LNE)
- Accessibility

The above non-spatial suitability considerations are addressed in greater detail in Section 7.1.3.

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 (2000) used API techniques to assess 135 000 hectares of cleared farmland in the Upper North East region (North of the Bruxner Highway) and mapped the extent of remnant vegetation. The results for the study area pertaining to land classed by structural vegetation and ALCC data as “cleared” suggest that up to 40 per cent of such land still may contain native vegetation. The study was restricted to a defined area north of the Bruxner Highway and other areas within the Upper and Lower North East Regions would have other proportions of remnant native vegetation due to differing land use practices.

TABLE 6.D - REMNANT VEGETATION ON CLEARED PRIVATE LAND FOR SELECTED STUDY AREA IN UPPER NORTH EAST CRA REGION***

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.
** Note that this study covered the Upper North East CRA Region North of the Bruxton Highway only and provides an indication of potential influence of remnant vegetation.
*** Aerial Photo Interpretation was unable to break this class any further so is necessarily a coarse estimate.

Other themes

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

- Utility easements (including powerlines, pipelines, roads, infrastructure)
- Native grasslands in LNE (Referred to in UNE CRAFTI Category 'G')
- Accessibility (proximity to roads or surrounded by inaccessible land uses)

6.3 RESULTS

Tables 6.E, 6.F and 6.G indicates the cumulative reduction in area associated with various suitability exclusions to result in the final potentially suitable areas. Map 6.a shows land use in the Upper and Lower North East NSW CRA regions. The data integration chapter shows this information in a summarised form which is provided for usage in the economics chapter.

TABLE 6.E - SUITABILITY EXCLUSIONS FOR UPPER NORTH EAST NSW

Upper North East		Hoop pine (hectares)				Slash pine (hectares)				Hardwood (hectares)			
Land Use	Avail	Unsuitable	Low	Medium	High	Unsuitable	Low	Medium	High	Unsuitable	Low	Medium	High
Coastal Grazing/Dairying	Yes	83 000	9 000	19 000	14 000	83 000	9 000	10 000	23 000	83 000	9 000	9 000	24 000
Extensive Cropping	Yes												
Grazing/Grassland	Yes	343 000	156 000	116 000	65 000	346 000	77 000	186 000	72 000	345 000	129 000	110 000	96 000
Horticulture	No												
Intensive Animal Production	No												
Intensive Cropping	Yes	16 000	4 000	14 000	32 000	16 000	4 000	11 000	35 000	15 000	4 000	5 000	42 000
Mining/Quarrying	No	1 000				1 000				1 000			
Mixed Cropping	Yes	38 000			15 000	38 000			15 000	38 000	11 000	4 000	
Mixed Grazing	Yes	504 000	137 000	47 000	8 000	506 000	80 000	95 000	16 000	502 000	172 000	12 000	10 000
No Data	No	1 000				1 000				1 000			
Public Land	No	1 308 000				1 308 000				1 308 000			
Recreation	No												
Rural Residential	No	3 000				3 000				3 000			
Tablelands Grazing	Yes	871 000	11 000	61 000		870 000		65 000	9 000	869 000	69 000	5 000	
Urban	No	9 000				9 000				9 000			
Utilities/Other	No	6 000				6 000				6 000			
Waterbodies	No	14 000				14 000				14 000			
		3 197 000	317 000	257 000	134 000	3 201 000	170 000	367 000	170 000	3 194 000	394 000	145 000	172 000

TABLE 6.F – SUITABILITY EXCLUSIONS FOR LOWER NORTH EAST NSW

Lower North East		Hoop pine (hectares)				Slash pine (hectares)				Hardwood (hectares)			
Land Use	Avail	Unsuitable	Low	Medium	High	Unsuitable	Low	Medium	High	Unsuitable	Low	Medium	High
Coastal Grazing/Dairying	Yes	184 000		78 000	85 000	182 000		44 000	121 000	186 000	23 000	69 000	70 000
Extensive Cropping	Yes	58 000	5 000	4 000		58 000		8 000	1 000	58 000	2 000	4 000	2 000
Grazing/Grassland	Yes	752 000	60 000	74 000	14 000	751 000	7 000	114 000	28 000	752 000	94 000	48 000	5 000
Horticulture	No												
Intensive Animal Production	No												
Intensive Cropping	Yes	29 000	1 000	10 000		29 000		7 000	3 000	29 000	8 000	2 000	
Mining/Quarrying	No	9 000				9 000				9 000			
Mixed Cropping	Yes	48 000		1 000	11 000	48 000		2 000	10 000	48 000	5 000	7 000	
Mixed Grazing	Yes	806 000	37 000	199 000	30 000	807 000	2 000	186 000	76 000	814 000	115 000	120 000	23 000
No Data	No	1 000				1 000				1 000			
Public Land	No	2 091 000				2 091 000				2 091 000			
Recreation	No												
Rural Residential	No	179 000				179 000				179 000			
Tablelands Grazing	Yes	967 000		3 000	1 000	967 000		2 000	2 000	967 000	3 000		
Urban	No	39 000				39 000				39 000			
Utilities/Other	No												
Waterbodies	No	25 000				25 000				25 000			
		5 188 000	103 000	369 000	141 000	5 186 000	9 000	363 000	241 000	5 198 000	250 000	250 000	100 000

TABLE 6.G - SUITABILITY EXCLUSIONS FOR ENTIRE NORTH EAST REGION

Total		Hoop pine (hectares)				Slash pine (hectares)				Hardwood (hectares)			
Land Use	Avail	Unsuitable	Low	Medium	High	Unsuitable	Low	Medium	High	Unsuitable	Low	Medium	High
Coastal Grazing/Dairying	Yes	267 000	9 000	97 000	99 000	265 000	9 000	54 000	144 000	269 000	31 000	78 000	94 000
Extensive Cropping	Yes	58 000	5 000	4 000		58 000		8 000	1 000	58 000	2 000	5 000	2 000
Grazing/Grassland	Yes	1 095 000	216 000	189 000	79 000	1 096 000	83 000	300 000	100 000	1 097 000	223 000	158 000	101 000
Horticulture	No												
Intensive Animal Production	No												
Intensive Cropping	Yes	44 000	5 000	24 000	32 000	45 000	4 000	18 000	39 000	44 000	12 000	7 000	42 000
Mining/Quarrying	No	10 000				10 000				10 000			
Mixed Cropping	Yes	85 000		1 000	26 000	86 000		3 000	25 000	87 000	16 000	11 000	
Mixed Grazing	Yes	1 310 000	174 000	246 000	38 000	1 313 000	82 000	281 000	92 000	1 316 000	287 000	132 000	33 000
No Data	No	3 000				3 000				3 000			
Public Land	No	3 399 000				3 399 000				3 399 000			
Recreation	No												
Rural Residential	No	182 000				182 000				182 000			
Tablelands Grazing	Yes	1 838 000	11 000	64 000	1 000	1 837 000		66 000	11 000	1 836 000	73 000	5 000	
Urban	No	48 000				48 000				48 000			
Utilities/Other	No	6 000				6 000				6 000			
Waterbodies	No	39 000				39 000				39 000			
		8 384 000	420 000	625 000	275 000	8 387 000	178 000	730 000	412 000	8 394 000	644 000	396 000	272 000

Map 6.A – Land Use and Land Tenure

7. DATA INTEGRATION

7.1 METHOD

Integration of the land suitability layers produces a composite land suitability layer. This composite layer can 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 is combined with the outputs of capability modelling to create a plantation potential layer that takes into account both predicted productivity and the land suitability of any given area. The results of this process are discussed 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 were rasterised to the same resolution and origin as the land cover layer. This avoids subsequent resampling 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 (Table 7.A). 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, as these are not considered appropriate for industrial scale development.

TABLE 7.A –CUMMULATIVE REDUCTION IN NET SUITABLE AREA

		Upper NE			Lower NE			Total		
		Low	Medium	High	Low	Medium	High	Low	Medium	High
Hoop pine		hectare	hectare	hectare	hectare	hectare	hectare	hectare	hectare	hectare
	Gross Area Capable	1 144 000	1 073 000	516 000	348 000	1 396 000	842 000	1 492 000	2 470 000	1 358 000
	Native Vegetation	518 000	393 000	183 000	145 000	581 000	241 000	663 000	973 000	424 000
	CRAFTI#	372 000	311 000	163 000	145 000	581 000	241 000	518 000	891 000	403 000
	Land Use	340 000	292 000	156 000	131 000	467 000	185 000	472 000	759 000	341 000
	Slope gt 18 degrees	336 000	284 000	150 000	119 000	421 000	172 000	455 000	705 000	323 000
	Patch Size < 25 hectare	317 000	258 000	134 000	103 000	368 000	141 000	420 000	626 000	275 000
	Net Area Suitable	**317 000**	**258 000**	**134 000**	**103 000**	**368 000**	**141 000**	**420 000**	**626 000**	**275 000**
Pinus elliottii										
	Gross Area Capable	565 000	1 506 000	662 000	28 000	1 361 000	1 197 000	594 000	2 866 000	1 859 000
	Native Vegetation	270 000	591 000	233 000	15 000	552 000	400 000	285 000	1 142 000	632 000
	CRAFTI#	205 000	440 000	201 000	15 000	552 000	400 000	220 000	991 000	601 000
	Land Use	184 000	410 000	194 000	14 000	463 000	305 000	199 000	873 000	499 000
	Slope gt 18 degrees	182 000	400 000	188 000	13 000	414 000	284 000	196 000	814 000	472 000
	Patch Size < 25 hectare	168 000	367 000	170 000	10 000	364 000	241 000	178 000	731 000	411 000
	Net Area Suitable	**168 000**	**367 000**	**170 000**	**10 000**	**364 000**	**241 000**	**178 000**	**731 000**	**411 000**
Hardwood										
	Gross Area Capable	1 690 000	574 000	469 000	1 126 000	960 000	500 000	2 816 000	1 534 000	969 000
	Native Vegetation	644 000	228 000	222 000	397 000	414 000	155 000	1 041 000	643 000	377 000
	CRAFTI#	460 000	183 000	203 000	397 000	414 000	155 000	857 000	597 000	358 000
	Land Use	423 000	171 000	194 000	338 000	317 000	128 000	761 000	488 000	322 000
	Slope gt 18 degrees	416 000	166 000	188 000	296 000	295 000	120 000	712 000	461 000	308 000
	Patch Size < 25 hectare	393 000	145 000	172 000	251 000	250 000	100 000	644 000	396 000	272 000
	Net Area Suitable	**393 000**	**145 000**	**172 000**	**251 000**	**250 000**	**100 000**	**644 000**	**396 000**	**272 000**

CRAFTI data are not available for the Lower North East, hence no reduction. Cannot include estimate as Net Suitable area as it requires a spatially based figure.
Totals may vary due to rounding

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, the available data were used to estimate the potential effect of these suitability constraints. These potential effects are described below, but they have not been applied empirically to the results as the overlap between relative contributions cannot be easily determined, and there are still some themes for which estimates are not available.

Lower North East CRAFTI estimate.

In Upper North East (UNE), there are noticeable differences in the extent of woody vegetation as described by the ALCC land cover classification and the CRAFTI air photo mapping. Many of these differences relate to the manner in which the data were collected, and the intended use of the dataset. But the presence of aspect related difference in forest cover in some portions of the ALCC landcover data suggest that in some circumstances, the ALCC data under-estimates the extent of woody vegetation (chiefly in sparser forests in the west of the study area).

Because of this, both ALCC and CRAFTI are used for UNE. But since CRAFTI air photo mapping was not available for Lower North East (LNE), no spatial estimate could be made.

Remnant native vegetation

Both the CRAFTI and ALCC have minimum limits on the size and type of native vegetation they can detect. Previous work has suggested that cleared farmland in the assessed areas may still contain significant native vegetation remnants. This does not however mean that land containing these remnant areas is excluded from potential plantation establishment, in the future they will need to be assessed in accordance with the provisions of the *Plantations and Reafforestation Act (1999).*

Environmental Exclusions

In addition to consideration of areas of remnant native vegetation in commercial timber plantation design, current codes of practice generally prescribe that drainage lines be buffered by an uncultivated distance each side of the drainage line. This prescription normally results in an unplanted zone along drainage lines which can mean a minor reduction in plantable area, although this is difficult to quantify at a regional scale because it is linked with site specific factors such as topography and exclusions due to native vegetation.

Other environmental and related considerations which may ultimately affect the area available for commercial plantation establishment (but are not always spatially quantifiable) include:

- Slope
- Occurrence of threatened and vulnerable species (flora and fauna) and associated protection zones
- Soil erodability
- Presence of heritage items (Aboriginal and European)
- Proximity to streams

Acid sulphate soils

Some coastal areas in the study area are subject to acid sulphate soils. In these areas, disturbance of a sulphide mineral rich layer can result in the production of acid runoff (DLWC, March 1998). Acid sulphate risk does not preclude the use of an area for plantations, but such areas will need additional field assessment to determine the extent of any sulphate soil layers, and to determine if plantation management activities can be conducted in a way that reduces acid runoff risk to an acceptable level. As it is a management consideration rather than an outright exclusion, it is mapped in this study, but is not excluded as an unsuitable area.

Acid sulphate risk has been mapped for the majority of the area. But to give complete coverage of the study area, this mapped data were intersected with terrain models to derive a modelled distribution of potential acid sulphate soils. It was found that mapped acid sulphate risk areas could be closely described by mapping areas with 0 to 1 degree of slope (i.e., quite flat) in areas less than 10 metres above sea level. This distribution also agrees very closely with the described distribution that appears in DLWC (March 1998).

Acid sulphate risk exists in approximately 200 000 hectares out of the 1.4 million hectares of land identified as being both capable and suitable. Map 7.a illustrates the extent of areas subject to acid sulfate risk, while Table 7.B estimates the maximum likely impact. For example, up to 31 per cent of highly productive and suitable eucalypt areas are potentially subject to acid sulphate risk. It is essential to note that this is a **risk** and that site assessment is required to determine actual status.

TABLE 7.B - ESTIMATED MAXIMUM IMPACT OF POTENTIAL ACID SULFATE SOIL (PASS) RISK*

Productivity Class	*Pinus elliottii*	*Araucaria cunninghamii*	Hardwood spp.
Low	8%	6%	6%
Medium	11%	16%	15%
High	22%	21%	31%

* Potential risk area as a percentage of total capable/suitable area

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.C shows the areas of cleared private land by productivity class potentially suitable for plantation establishment. (Note that the unsuitable category includes both unsuitable and incapable land for growing commercial timber plantations).

TABLE 7.C - GROSS PRODUCTIVITY OUTPUTS BY PRODUCTIVITY CLASS

	UNE	**LNE**	**TOTAL**
P. elliottii	hectare	hectare	hectare
Incapable & unsuitable	3 202 000	5 185 000	8 387 000
Low	168 000	10 000	178 000
Medium	367 000	364 000	731 000
High	170 000	241 000	411 000
L+M+H	**705 000**	**615 000**	**1 320 000**
Hoop pine			
Incapable & unsuitable	3 198 000	5 189 000	8 386 000
Low	317 000***	103 000***	420 000***
Medium	258 000***	368 000***	626 000***
High	134 000	141 000	275 000
L+M+H	**709 000**	**612 000**	**1 321 000**
Hardwood			
Incapable & unsuitable	3 196 000	5 199 000	8 395 000
Low	393 000	251 000	644 000
Medium	145 000	250 000	396 000
High	172 000	100 000	272 000
L+M+H	**710 000**	**601 000**	**1 312 000**

***Whilst medium and low capabilities have been modelled for Hoop Pine, it is not recommended that they be established on these sites.

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

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

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

- level of reliance on income from farming activities;
- limitations in flexibility of property used 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; and
- 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, and dairying are economically sustainable around the Coffs Harbour/Dorrigo 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.

Map 7.a – Distribution of Acid Sulphate Soils

8. ECONOMIC ANALYSIS

8.1 AIM

This analysis assessed the economic potential for commercial timber plantation establishment in the Upper and Lower North East CRA regions of New South Wales by comparing the estimated value of land currently under agricultural use with the potential value from selected plantation developments for timber production. Environmental, agricultural and aesthetic costs and benefits associated with plantation development in the region were not included in the analysis.

The eventual level of plantation development within these regions 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.

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. Actual plantation capability and suitability will differ at a site specific level.

This analysis follows on from previous research by ABARE (see Burns, Walker and Hansard 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 net present values (NPV) associated with the development of plantation forests in the region. The mill door prices of potential new mill developments were set to generate average stumpage values, using transport costs calculated from mills to all potential plantation sites. These projected stumpages were compared with anticipated stumpages for north coast plantations as described below.

The NPV of a single plantation rotation was 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 an equal area of plantation is developed each year and 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

The key parameters examined for the purpose of this analysis were stumpage price, yield and rotation length, and establishment costs (see tables 8.A-8.C and Appendix 5 for more details). Data were collected from various sources to represent the costs, yields and returns potentially available to the private investor or landowner establishing plantations in northern NSW, taking into account the experience of the State Forests hardwood and softwood plantations programs. Sensitivity analysis was conducted on several key parameters relating to plantation potential to account for the uncertainty and variability of forest product prices, establishment costs and yields, especially in hardwood sawlog regimes.

Stumpage prices for softwood and hardwood logs were derived from regional datasets as well as prices available in other, more established plantation regions in Australia.

Softwood yields were derived from corporate data from State Forests plantations (Appendix 7). Hardwood yields were derived from State Forests hardwood yield model – Plantation Yield Predictor (PYP). In both cases three conservative productivity levels with corresponding product yields were ascribed to land based on the output surfaces from 3PG. As discussed in Section 3.1.2, higher yields than the baseline scenario are being achieved in the region using best establishment and silvicultural practices. However given the magnitude of yields currently achieved by some older pre-1994 plantations (due to a range of factors including species selection, site quality, establishment and management techniques and silvicultural treatments) an alternate, ‘conservative’ yield scenario was developed for hardwood plantations. This conservative yield scenario (which varies both MAI and rotation length) is described below.

Costs of establishment and maintenance likely to be experienced on the north coast were categorised into broad-scale and small-scale regimes. The broad-scale regime represents cost savings possible with increased economies of scale.

8.2.2 Sensitivity Analysis

Two stumpage price regimes were compared for both softwood and hardwood plantations. Under the higher price regime, the stumpage price of hardwood and softwood sawlogs and pulplogs was increased by 10 per cent from the base rate. Thus the price of softwood sawlog thinnings and HQS hardwood sawlogs increased from $25 to $27.50 per cubic metre and the price of softwood clearfall sawlogs and HQL hardwood sawlogs increased from $50 to $55 per cubic metre. Pulplog prices increased from $15 to $16.50 per cubic metre and veneer log prices increased from $60 to $66 per cubic metre

TABLE 8.A - INDICATIVE NORTH COAST NSW STUMPAGES USED FOR ECONOMIC ANALYSIS

Product	Base Stumpage Rate $/m³	Higher Stumpage Rate $/m³
Hardwood veneer	$60	$66
High Quality Large softwood and hardwood sawlogs	$50	$55
High Quality Small hardwood and softwood thinnings	$25	$27.50
Pulpwood	$15	$16.50

Two cost scenarios were modelled for Slash pine and hardwood commercial plantation viability, relating to a broad-scale and small-scale establishment and maintenance cost regime. The broad-scale costing regime would be encountered in plantation development on areas of land greater than 1000 hectares and consist of establishment and post-establishment costs of $1400 and $300 per hectare respectively, with maintenance costs of $40 per hectare per year. The smaller-scale costing regime applies to plantation establishment on smaller land parcels where economies of scale are less likely to be available. As Hoop pine plantations are generally confined to smaller high productivity areas of the region, no sensitivity analysis was conducted on this species for establishment costs. The establishment, post-establishment and maintenance costs for Slash pine and Hardwoods as well as Hoop pine used in this analysis are described in the table below.

TABLE 8.B - INDICATIVE NORTH COAST NSW ESTABLISHMENT COSTS USED FOR ECONOMIC ANALYSIS

	Broad-Scale Slash pine/Hardwoods $/hectare	Small-Scale Pine/Hardwoods $/hectare	Hoop pine $/hectare
Year 0 Establishment	1400	1700	1800
Year 1 Establishment	300	300	200
Annual maintenance	40	90	40
Roading – first thinning	300	100	300
Roading – second thinning and final harvest	0	25	0
Marketing – first thinning	100	71 + $0.5/m³	100
Marketing – second thinning and final harvest	100	38 + $0.5/m³	100
Pruning (yrs 9, 11)	-	-	350, 500

In addition to the above analysis, further scenarios were run for the yield parameters assumed for hardwood plantations in UNE and LNE. The conservative yield analysis assumes lower growth rates and longer rotation lengths for plantations on each productivity class. For hardwoods, the rotation lengths were increased from 34 to 40 years on low sites, from 34 to 35 years on medium sites and from 22 to 30 years on high productivity sites. Related to this, the mean annual increments (MAI's) were reduced from 15m³/ha.yr to 12m³/ha.yr on low productivity sites, from 18m³/ha.yr to 15m³/ha.yr on medium sites and from 22m³/ha.yr to 18m³/ha.yr on high productivity sites. Additionally, the proportion of sawlogs in total yields for each of these productivity classes was reduced (see Table 8.C). No sensitivity was conducted for softwood plantation growth rates as there is more certainty regarding the yields of softwood plantations within the regions.

TABLE 8.C - INDICATIVE NORTH COAST NSW PRODUCTIVITIES AND ROTATION LENGTHS USED FOR ECONOMIC ANALYSIS

Yield Scenario	**Hardwoods (Baseline)**		**Hardwoods (Conservative)**		**Slash pine**		**Hoop pine**	
Site Productivity	MAI m^3/ha.yr	Rotation Length (years)	MAI m^3/ha.yr	Rotation Length (years)	MAI m^3/ha.yr	Rotation Length (years)	MAI m^3/ha.yr	Rotation Length (years)
Low	15	34	12	40	8-10	39	-	-
Medium	18	34	15	35	15	30	-	-
High	22	22	18	30	20	30	25	45

8.2.3 Assumptions

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

- Five plantation species are modelled in the region: *Pinus elliottii* and *Araucaria cunninghamii* softwood plantations, as well as *Eucalyptus grandis, E. pilularis and Corymbia variegata* hardwood plantations. The three hardwood species were modelled for high, medium and low productivity classes respectively, as discussed previously in this report.
- All regimes modelled were sawlog regimes. Six log types are produced from plantations in the region: veneer, small and large softwood sawlogs from thinned and clearfelled *P. elliottii* and *A. cunninghamii* plantations, high quality large (HQL) and high quality small (HQS) hardwood sawlogs from the *E. grandis/E. pilularis/C. variegata* plantations, and pulplogs from all plantation types;
- There is potential to develop additional capacity to process sawlogs in Casino, Kyogle, Grafton, Kempsey, Whiporie, Wauchope, Gloucester, Taree, Bellingen and Gosford. The mill door prices for these mills are calculated using average stumpage prices provided by State Forests of NSW. The stumpage prices for individual plantation sites vary in the model based on the haulage distance to each assumed mill location. No account is taken of the potential rents and volumes available in the region to develop this capacity;
- There is potential to develop additional woodchipping capacity for pulplogs and it is assumed to be developed in Brisbane and Newcastle. As with the sawlog mills, 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 mills used in the analysis and their cost and output characteristics are assumed to be continually repeated once they reach shutdown age;
- Plantation establishment and management costs are independent of the size of investment, type of investor, individual site conditions, existing roading etc;
- The Upper and Lower North East CRA regions are small regions, such that forest product prices are determined elsewhere independently of volumes of timber produced in the regions;
- Costs and returns relating to plantation and agricultural activities are based on 1998 levels and are assumed to be constant in perpetuity;
- In the model, the estimated values of agricultural land are used as a proxy for the long term returns from existing agricultural activities that compete against plantations; and
- A real discount rate of seven per cent is used for all calculations.

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

While this modelling framework assumes the development of additional timber processing capacity, there are a number of existing timber processing facilities in the UNE and LNE CRA regions that utilise the available plantation resource. Approximately 60 000 m^3 of hardwood logs and 176,000 m^3 of softwood logs (primarily *P.radiata*) were harvested from plantations in 1998-99 and processed by existing timber mills for sawn timber, veneer, poles and other products, while in excess of 80 000 m^3 of pulpwood was exported via facilities at Newcastle and Brisbane (State Forests of NSW corporate dataset).

The increasing volumes of hardwood plantation grown material processed by existing native forest timber industry indicate the industry is making a transition from mature native forest material to native forest regrowth and plantation grown hardwood and softwood timbers. Nevertheless, further investment in capital intensive plantation processing capacity is required in the region to support further increases in the hardwood and softwood plantation resource.

Grazing activities account for a significant proportion of the agricultural land use in the region, particularly dairy and beef grazing. Additionally, some horticultural activities exist in the region, however these land uses were masked out of this study as land value information was unavailable for these activities and plantations would be unlikely to compete with them. Land values were estimated from ABARE’s AAGIS (Australian agricultural and grazing industries survey) and ADIS (Australian dairy industry survey) farm survey data. These land values are based on landholder’s estimates of the value of their land. Spatial representations of these land values were derived by regressing the land value data with rainfall, the distance to urban centres and estimated land use.

8.2.4 Land use competition

Due to data and methodology constraints, the use of land price data in this study assumes that plantation development must completely displace existing land use. In many cases, however, forestry may be integrated with existing land uses, often resulting in lower costs and additional benefits. These additional benefits may include stock shelter, catchment protection and amelioration of land degradation.

This issue could be significant in the determination of plantation potential in the region, especially given the increasing prominence on farm forestry and joint venture plantation arrangements with landholders. To address these methodology issues, the results of this study present potential plantation land values as a percentage of the estimated agricultural land price. These ranges could be used as a proxy for landowners anticipating commercial and non-commercial benefits in addition to timber returns. If, for example, the landowner priced the value of these additional benefits at 10 per cent of the total farm enterprise, plantations would be regarded as an economically suitable investment if the potential plantation land values exceeded 90 per cent of the estimated land value under agriculture.

8.3 RESULTS

Simulation results for combinations of the sensitivity analysis described above are presented in Table 8.D.

8.3.1 Softwood plantations

There is significant economic potential for additional softwood sawlog plantations in the CRA region, particularly *P. elliottii* (Table 8.D, Map 8.c and 8.d). The total economic plantation area (where potential plantation values exceed estimated agricultural land values) in the scenario with high stumpage prices and broad-scale plantation costs is over 68 000 hectares. Only a relatively small area is suitable for *A. cunninghamii* plantations (Map 8.e and 8.f). This area overlaps with the area suitable for *P. elliottii*, implying some competition between the two softwood species.

The entire economically suitable area is located on high productivity land. The potential annual sawlog yields from potential new softwood plantations exceed one million cubic metres. This implies significant potential for large-scale timber processing facilities.

In addition, more than 100 000 hectares of land in the region has potential plantation values that are above 90 per cent of the estimated agricultural values in this scenario. 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.

The majority of this marginal area is also located on high productivity land, and thus provides significant additional potential for timber production. Thus, given sufficient investment in processing capacity, the realisation of these marginal areas for plantation development, through the realisation of other benefits on top of timber returns, could have significant implications for regional production and employment in the plantation sector.

With higher stumpage prices for softwood logs, the competitiveness of plantations improves substantially. Under this scenario, the economic area increases by 143 per cent to 166 000 hectares. With higher stumpage prices, some land of medium quality becomes economically suitable. Hence the potential annual sawlog yields increase substantially, but to a lesser extent than the area planted. Hoop pine potential also increases substantially in this scenario.

While these results indicate significant softwood potential in the region, the realisation of this potential would require significant investment in timber processing capacity.

Scenarios with the higher assumed plantation costs, approximating those borne by small growers, demonstrate dramatic reductions in plantation potential. The area with potential plantation values for *P. elliottii* above 90 per cent of estimated agricultural values is only 4 000 hectares when high stumpages are assumed. The volume of timber deriving from this area would be insufficient to encourage the development of large-scale processing facilities, as assumed in this model.

TABLE 8.D - POTENTIALLY ECONOMIC AREAS WITHIN ENTIRE UPPER AND LOWER NORTH EAST CRA REGIONS

P. elliottii

Scenario	Base Stumpage	High Stumpage	Small-scale Costs	Broad-scale Costs	Baseline Yields	Competitive Area [a]							
						above 100% land value		90-100% land value		75-90% land value		50-75% land value	
						Area ha	**Yields m³/yr [b]**	**Area ha**	**Yields m³/yr [b]**	**Area ha**	**Yields m³/yr [b]**	**Area ha**	**Yields m³/yr [b]**
1	✔		✔		✔	0	0	0	0	26,106	461,206	373,926	6,606,026
2		✔	✔		✔	28	495	3998	70,631	160,096	2,828,363	240,690	4,252,190
3	✔			✔	✔	68,401	1,208,418	101,389	1,791,206	165,690	2,837,190	681,465	8,493,515
4		✔		✔	✔	166,237	2,936,853	83,336	1,471,459	274,769	3,811,086	558,086	6,875,125

A. cunninghamii

Scenario	Base Stumpage	High Stumpage	Small-scale Costs	Baseline Yields	Competitive Area [a]							
					above 100% land value		90-100% land value		75-90% land value		50-75% land value	
					Area ha	**Yields m³/yr [b]**	**Area ha**	**Yields m³/yr [b]**	**Area ha**	**Yields m³/yr [b]**	**Area ha**	**Yields m³/yr [b]**
1	✔		✔	✔	75	1,883	25,536	641,237	216,655	5,440,448	32,462	815,157
2		✔	✔	✔	25,611	643,121	60,611	1,522,009	188,283	4,727,995	223	5,600

E. grandis/E. pilularis/C. variegata

Scenario	Base Stumpage	High Stumpage	Small-Scale Costs	Broad-Scale Costs	Baseline Yields	Conservative Yields	Competitive Area [a]							
							above 100% land value		90-100% land value		75-90% land value		50-75% land value	
							Area ha	**Yields m³/yr [b]**	**Area ha**	**Yields m³/yr [b]**	**Area ha**	**Yields m³/yr [b]**	**Area ha**	**Yields m³/yr [b]**
1	✔		✔		✔		48	659	9620	132,056	89,748	1,208,142	753,306	9,248,417
2		✔	✔		✔		12,933	177,491	24,896	340,237	261,516	3,449,369	767,323	9,100,199
3	✔			✔	✔		152,023	2,013,408	286,070	3,482,520	603,727	7,067,311	215,572	2,622,360
4		✔		✔	✔		385,974	4,896,805	416,473	4,931,789	353,466	4,131,121	128,158	1,507,583
5	✔		✔			✔	0	0	0	0	0	0	92,760	915,232
6		✔	✔			✔	0	0	0	0	978	9,650	172,061	1,673,566
7	✔			✔		✔	39	385	9449	93,230	54,170	530,334	362,513	3,183,147
8		✔		✔		✔	8,850	129,822	17,882	176,436	119,274	1,155,475	433,325	3,626,674

a Comparison of potential plantation land values to estimated values of agricultural land. **b** Annual potential sawlog yield when forest normalised

8.3.2 Hardwood plantations

The hardwood plantation resource in the region is currently in a process of expansion, through both public and private investment, with an emphasis on sawlog production. As stated in previous sections, a concerted effort in the expansion of the public hardwood plantation resource commenced in 1994. However, as a large proportion of existing plantations have not yet reached harvestable age, some uncertainty exists relating to the potential yields, the establishment and management costs and the potential stumpage values of these plantations. It was due to this uncertainty that several scenarios were modelled as described above.

Due to uncertainty in species performance and quality across the region, the analysis used *E. grandis* for high site quality, *E. pilularis* for medium site quality and *C. variegata* for low site quality. In fact, it was possible to run productivity layers for each of these hardwood species, but in order to simplify the reporting requirements and economic analysis, the modelling of each species was restricted to the productivity class in which it performed best.

Table 8.D indicates that the economic suitability of hardwood sawlog regimes in the upper and lower north east of NSW is highly sensitive to a number of factors. Under the scenario with base parameters (base stumpage prices, broad-scale plantation costs and baseline yields), the potential hardwood plantation area is more than 150 000 hectares. This has the potential to derive, after 22 years, annual sawlog yields of more than 2 million cubic metres, capable of supporting significant investments in processing capacity. In addition, an even larger area has potential plantation values that are between 90 and 100 per cent of the estimated agricultural values. If additional non-timber benefits could be realised from these plantation areas, such as the derivation of carbon credits, the potential plantation estate in this region could increase substantially.

However, these results are highly sensitive to changes in the parameters assumed in this scenario. In the broad-scale scenario where the base stumpage prices are increased by 10 per cent, the economically viable plantation area increases to 385 000 hectares, supporting potential annual sawlog yields of almost 5 million cubic metres after 34 years.

When the plantation establishment and maintenance costs increased or the yields are reduced, plantation potential across the regions decreases significantly. With the baseline stumpage price and yield parameters held constant, the higher plantation costs potentially incurred by small growers causes plantation suitability to fall to levels insufficient to support an adequate processing infrastructure.

However, an important consideration with small growers is that, in addition to potential timber and non-timber (such as carbon) commercial returns, landholders are in a unique position to combine these forestry activities with existing land uses to derive improvements in agricultural productivity and sustainability. Consequently, if these non-commercial benefits were considerable, in the order of about 25 per cent of land values, it may be economic for a large proportion of landholders in the region to adopt such forestry activities. If this were the case, table 8.D suggests that the potential annual sawlog yields deriving from this investment would be capable of supporting large-scale processing facilities.

Table 8.D shows that the results for hardwood plantations are even more sensitive when potential yields are changed. Even with higher stumpage prices, plantation potential with a conservative yield scenario would be insufficient to support investments in processing infrastructure, unless considerable non-timber benefits were achievable.

8.4 DISCUSSION

As a modelling approach, the results of the REAP analysis are only indicative of the potential of the plantation industry. The broad-scale of the analysis means that the results are not applicable to the individual farms within the regions.

In the REAP analysis, agricultural land values are calculated from the average estimates of the land values provided by landowners in ABARE's farm surveys, over the 10 years prior to 1997. The estimated agricultural land values were used because a comprehensive data set of the current profitability of agricultural activity is not available at the scale required for this analysis. For the purpose of this study, the estimates of agricultural land value from the ABARE farm surveys were considered to be the best, most comprehensive estimate available of the economic return to the current agricultural land use.

However, in some situations estimated land values may differ from the anticipated agricultural returns. For example, this may occur where, urban influences are significant, where farmers include lifestyle considerations into their estimated land values or the market values of agricultural products fluctuate against the inherent land value. Alternatively, some landowners, such as those seeking a diversified income, or absentee landowners seeking a low maintenance enterprise, may compare the return on investment from forestry with the existing agricultural enterprise, without taking into account the actual agricultural land value. However, as this information is more qualitative than quantitative and related to the landowners' preferences, it is very difficult using the methods in this study to include in calculations of the return to an agricultural enterprise or the land value. In an example of a case study incorporating some of these more qualitative variables into the analysis, EFS/CARE (1997) compared the net farm income from dryland beef cattle with a hypothetical industrial scale forest enterprise on the north coast of NSW. They found forestry could provide returns significantly higher than the returns from agricultural enterprise assuming the landholder had access to a mature forest resource and markets from which to trade.

The net value of production (NVP) approach, used to compare the economic returns from plantations relative to the existing agricultural land use in the REAP model, has limitations. In providing an absolute measure of the return on an individual enterprise, selecting the appropriate discount rate is problematic. For example, a lowering of the discount rate used in this analysis from 7 per cent to say 3 per cent would increase the area of land considered viable for forestry development. Conversely, a higher discount rate would decrease the competitiveness of forestry in this analysis.

Alternative, approaches to determining the economic potential of plantations, such as an internal rate of return (IRR) analysis, are available. However, these approaches also bear some limitations. An IRR approach can provide an indicative estimate of the potential economic returns from planting trees on agricultural land, but it should be combined with a similar analysis of the returns from the existing agricultural land use. On highly productive land that can produce relatively high returns from plantations (greater than 10 per cent), the land is likely to produce similar high returns from agriculture.

NPV and IRR both have benefits and limitations as analysis tools used in establishing the economic viability of various enterprises. While the REAP model has some limitation, for this project it was considered to be the most appropriate economic analysis available to determine the plantation potential at the regional level.

The two methods of economic analysis discussed above can indicate positive cash flows at various discount rates to plantation owners. However, it should be noted that the majority of the return is achieved at the end of the plantation rotation compared with the regular cash flow accompanying alternative agricultural enterprises. This has been seen as a potential impediment to larger-scale investments in plantations. In recognition of this, certain joint-venture plantation schemes are offering landowners annual rental arrangements.

Incorporation of non-market benefits could contribute to the net present value of plantations and increase the area available to plantation development in the region. In earlier analysis using REAP, a market for carbon credits was included in the modelling work (Burns et al. 1999). Other possibilities include ‘salinity’ credits, with farmers in low lying areas, where salinity is a problem, encouraging (paying) farmers higher up the catchment, where rainfall infiltration is high, to plant trees. Planting trees in areas of high rainfall infiltration has the potential to reduce leakage into the watertable, thus reducing the risk of salinity further down the catchment. In conjunction with these initiatives, the concept of ‘biodiversity’ credits is also attracting attention. Both commercial and environmental plantations could benefit from this. State Forests has recognised the environmental benefits of plantations as a fundamental issue for promoting reforestation and has introduced both carbon and salinity driven investment portfolios for external investors.

The principle benefit of carbon trading to the grower is to bring forward cash flow to the forest investment, offsetting the establishment costs and therefore increasing the net present value of the investment. This generalisation however requires several qualifications. The rules for carbon emissions trading, as determined by the Kyoto Protocol, are yet to be defined. Until carbon trading formally commences, the price of carbon credits will remain uncertain. While the net present value of the investment will improve under the impact of early cash flow, this may be later offset by the need to buy back carbon credits to realise the wood. This is likely to cause problems for the investor if the price of carbon relative to wood were to rise after the initial sale of the credits. In addition, costs associated with measurement and marketing carbon credits may be prohibitive for some growers, particularly smaller growers. Discussion of these issues are can be found in Hansard et al. (2000).

In general, shorter rotation plantation forests have a higher average annual rate of growth than longer rotation forests. The challenge for sawlog production forests is to balance the slower growth rates with the higher returns provided by solid wood products (sawlogs and veneers). A compromise is usually achieved using silvicultural regimes providing pulpwood from early thinnings then concentrating productivity onto fewer high quality stems for sawlog production. The regimes used in this analysis aimed to produce sawlogs. However, if a bioenergy facility were to be introduced into the region, a higher price for pulpwood may be available. This may favour shorter rotation pulpwood regimes and potentially raising the overall profitability of the investment in plantation forestry for the region.

8.5 EMPLOYMENT

A variety of estimates exist for the potential employment impacts of plantation development. Burns et al (1999) used estimates derived by Lancefield consultants (1995), which assumed approximately 75 direct jobs per 10 000 hectares of plantations. This estimate included potential employment in the establishment, management, harvest and transport of plantation timber. However, these estimates represent gross effects of plantation development, and do not include potential employment losses in other sectors arising from land use change away from some activities.

In a report prepared for SFNSW on the impact of eucalypt forestry on the NSW economy, Regional Analysis and Strategies (1994) indicated the development of 100 000 hectares of plantation would have direct employment impacts of 1867 persons. This includes 127 positions in plantation establishment and management, 304 in logging and 1436 in processing. In a more recent study for SFNSW, CARE (1997) estimated that around 105 jobs would be created for each 10 000 hectares of plantation established.

Using the coefficients estimated in Regional Analysis and Strategies (1994), and assuming equal employment effects across the hardwood and softwood sawlog plantation sectors, the base case softwood analysis would suggest potential employment of approximately 87 people in plantation establishment and management, 208 people in harvest and hauling, and 983 people in sawlog processing. For the baseline potential hardwood plantation area (scenario 3), the coefficients would suggest the employment of about 193 people in plantation management, 462 people in harvesting and hauling, and 2,183 people in sawlog processing activities. However, the potential employment benefits from softwood and hardwood potential are not cumulative, as some areas may have been identified as suitable for both softwoods and hardwoods.

Map 8.a – Hardwood Competitiveness against Agriculture: Baseline Scenario – Broad-Scale

Map 8.b – Hardwood Competitiveness against Agriculture: Baseline Scenario – Small-Scale

Map 8.c – *Pinus elliottii* Competitiveness against Agriculture: Baseline Scenario

Map 8.d - *Pinus elliottii* Competitiveness against Agriculture: Optimistic Scenario

Map 8.e – Hoop pine Competitiveness against Agriculture: Baseline Scenario

Map 8.f - Hoop pine Competitiveness against Agriculture: Optimistic Scenario

9. CONCLUSION

There is considerable potential in the Upper and Lower North East regions for expansion of both softwood and hardwood commercial plantation estates, provided the assumed price, yield and cost parameters are achieved. These results differ from those reported in Burns et al (1999). There are two main reasons for this. Firstly, the plantation capability information has been redeveloped and improved markedly. Secondly, the previous study assumed high plantation establishment and management costs. The results presented in this study assume much lower costs that are in line with other estimates of private costs for other regions of Australia (see Burns et al (1999) for assumed costs for each NPI region). If the lower establishment and maintenance costs assumed in this study are realised, plantation potential in the region would increase substantially. Importantly though, the realisation of this potential will also depend on the development of large-scale timber processing facilities.

Additionally, an important consideration with small growers is that landholders are in a unique position to combine potential timber returns and environmental benefits from forestry activities with existing land uses to derive improvements in agricultural productivity and sustainability. These environmental benefits are as diverse as shade and shelter for livestock, windbreaks, land rehabilitation and erosion control as well as aesthetic values. Consequently, if these “non-commercial” benefits are recognised, then it may become economic for a large proportion of landholders in the region to adopt forestry activities.

It is also important to note that this study did not assess the plantation expansion potential of Radiata pine in the Northern Tablelands region of NSW, nor did it assess other hardwood species potentially suitable in this area. General indications are that significant areas of land in this region would be both capable and suitable for the establishment of Radiata pine and some other hardwood species, however, further economic assessment would be necessary to determine its potential extent.

In terms of some of the points raised in discussion sections, there are a number of areas where future work can make improvements to the techniques used in this project.
For assessing land capability and suitability, improvements can be made in the underlying soil typing and fertility data to improve the capability of the 3PG model to appraise the impact of localised topographical influences. Future work could concentrate on areas with significant plantation expansion potential, at a finer scale. However, the effort to improve the underlying soil information base would not be insignificant.

At a finer scale, it would be possible to introduce a fourth productivity class, for example >25m^3/ha.yr, representing the high productivity sawlog regimes possible on highly productive land.

In terms of the economic analysis, further work could be done on the sensitivity of various input variables to establish their relative importance to each plantation venture. Consideration should also be given to using variable discount or hurdle rates, in recognition that achieving maximum commercial rates of return may not be the imperative for plantation owners, especially smaller landholders. An alternative approach would be to compare returns from forestry against returns from agriculture in addition to the value of the agricultural land itself. This would reflect more accurately the situation on the north coast where diversification of farm income streams is preferred compared with the complete displacement of one land use for another.

As discussed previously, the implementation of a carbon trading regime could increase the net present value of plantation investment. This prospective increase would improve the potential plantation area on the north coast, with a particular emphasis on improving the economic viability of medium and low productivity areas. Although beyond the scope of this project, a recommendation for further study would be to quantify and model the implementation of a carbon trading regime on the potential area for plantations on the north coast and the net increase in the return to landholders and plantation owners.

As part of the outcomes arising from the introduction of the *Plantation and Reafforestation Act (1999)* in NSW, a Plantation Capability and Suitability Project covering most of the State has been commissioned and is due for completion in mid-2000. Although this new project will still consider plantation potential at the broad regional level, it will incorporate a number of the suggestions for improvements to future work, as outlined above.

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APPENDIX 1 - LITERATURE REVIEW

Ref No.	Author/ Date/Source	Title	Regions	Species	Data lists used	Capability	Suitability	Economic analysis	Maps used	Envelopes	Notes
1	ABARE, 1999	Forest plantations on cleared agricultural land in Australia	National Plantation Inventory Regions	*Pinus radiata, P. pinaster, E. globulus, E. nitens, E. regnans, E. grandis, E. pilularis, Corymbia variegata, P. caribaea, P. elliottii, A. cunninghamii Acacia mangium*	BRS rainfall data, Margules Groome Pöyry plantation yield, costs, final market prices and timber processing data, AUSLIG road coverages, ABARE farm surveys	Rainfall	Cleared agr land, agr land value	Plantation costs, timber processing costs (fixed & variable, recovery rates & capacity), transport costs, market prices, value of agr land	Maps of each region of: Current agr land use and value, plantation productivit y, potential land use	Varied depending on region and species	A national study using rainfall as a determinant for capability.
2	Allen, R & Assoc. 1982. Prepared for Vic LCC	An investigation of private land suitable for softwood production in SW District 1	Green Triangle	*P. radiata*	Land sales	Cleared freehold land, rainfall, temperature, soils, topography	Land use	Land sales	N/A	N/A	Area statements by productivity zones
3	Beckhouse J.A. ,1996, SFNSW	South East Eucalypt Plantation Program	SE NSW	Tablelands: *E. nitens Coastal: E. botryoides E. saligna*	Covers MAI quoted in literature. Rough yield schedules.	Gives most promising species for Coastal & Tablelands	Assesses other reports.	Market discussion. Summarises previous market assessments & opportunities Presents IRRs.	None	N/A	Review of south coast plantation prospects, including species lists, MAIs, site preparation requirements & management. Also lists further research requirements.

Ref No.	Author/ Date/Source	Title	Regions	Species	Data lists used	Capability	Suitability	Economic analysis	Maps used	Envelopes	Notes
4	Bonny, L., 1991, FCNSW, Research Paper No. 12	Growth of a *E. grandis* plantation following intensive silvicultural treatments applied in the first 6 years.	Northern NSW	*E.grandis*	Growth rates as MAI to 6 years	Site preparation methods to obtain MAIs.	N/A	N/A	N/A	33^{o}S-25^{o}S, grows best on lower slopes, deep soils of at least moderate fertility, 1500mm rainfall	Possible use in determining growth rates.
5	Booth, T.H and Jovanovic, T., 1991, CSIRO Division of Forestry, Report to the National Plantations Advisory Committee.	Integrating farming and forestry. Commercial wood production on cleared agricultural land. Appendix B. B1 “Identification of land capable of private plantation development. ”B4 “Environmental costs and benefits of establishing plantations on cleared agricultural land.”	All Australia	*E.diversicolor* *E.globulus* *E.grandis* *E.nitens* *E.pilularis* *E.regnans* *E.saligna* *A.mangium* *A.mearnsii* *A.melanoxylon* *P.radiata* *P.elliottii* *P.caribaea* *Araucaria cunninghamii*	SPANS GIS ESOCLIM AUSLIG	Climate, *rainfall, temperature* Soil: *physical, chemical* Topography: Pests: Diseases: Potential for irrigated plantations. Potential for hardwood on cleared land.	Discusses environ-mental costs/ benefits. Discusses constraints of: *seed availability, frost, pests, pathogens, salinity, water-logging*	Tas, Vic, WA case studies. Costs and returns for farming and forestry.	Soil 1:5 million Veg^{n} 1:5 million Climate 1:5 million	Rainfall >600mm/yr Cleared Vegetation Dry season<=6 months	Comprehensive analysis of plantation capability. Includes environmental, harvesting and research constraints. Environmental benefits of hydrological, soil, biodiversity, climatological, Economic studies. National scale study
6	Borschmann R. 1998. Prepared for Plantation Development Services for Plantations North East	DRAFT Plantation productivity potential of Blue Gum and Radiata Pine for NE Victoria	Victoria	*E. globulus, P. radiata*	Growth data derived from research trials and demo plantings	Cleared freehold land, rainfall, altitude, geology x rainfall classes	Distance from town centres	N/A	Plantation productivit y potential for *P. radiata* & *E. globulus*	N/A	Area statements by productivity classes

Ref No.	Author/ Date/Source	Title	Regions	Species	Data lists used	Capability	Suitability	Economic analysis	Maps used	Envelopes	Notes
7	Prepared by BRS under the Eden RFA process 1998	Identification of plantation expansion opportunities in NSW – Eden CRA region	Eden	*E. nitens, P. radiata*		Cleared private land. Climate (rainfall, temp, radiation & evaporation) Soil (geology, lithology, landscapes, depths, nutrient index). Topography. Site index	Land values, land tenure and use, productivity classes & buffer exclusions	NPV and productivity classes	Plantation potential maps for *P. radiata* & *E. nitens* Land tenure & use, NPV of Ag, NPV of plantations (baseline, high & low scenario)	N/A	Area statements
8	Bush et al 1998 Central Highlands(Vic) Prepared by BRS for Central Highlands RFA process	Plantation potential analysis	Murray Valley Victoria	*E. nitens, E. regnans P. radiata, A. melanoxylon*	Topographic models, soil suitability classes	Temperature, soil types and slope	Relationship between land property size and land price	Relationship between land property size and land price. Socio-economic analysis	Rainfall, soil capab. Land cover & tenure, land suitab by parcel size. Potential for *E. globulus, E. nitens, E. regnans, P. radiata, A. melanoxylon*	N/A	A report with area statements by suitability classes

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9	Bruskin S., SFNSW, research division, Coffs Harbour	Rainforest Plantings, material prepared for the joint venture plantation manager in response to a submission from the Big Scrub Landcare group	NSW North Coast	*various rainforest species*	Hoop pine log prices to 1994/95, NSW rainforest growth data, eucalyptus growth data, economic analysis,, climate/rainfall data	rainfall statistics, optimal growth rates for eucalypt and rainforest species, soil types for hoop and bunya pine, climate data	Market discussions, wood production schedules,	eucalypt, hoop pine, mixed rainforest plantations and cash flow summaries associated with varying ventures.	basic geology	N/A	detailed discussion of economics of rainforest species in plantations,
10	Bureau of Transport & Commun-ication, 1996, Economics Working Paper 23.	Costs of carbon sequestration through afforestation: greenhouse gas emissions Australian Transport.	National	*P. radiata*	Carbon sequestration rates for plantations.	Uses CSIRO 1991 study. Ref 1.	N/A	Costs	N/A	N/A	Utilised work from Booth and Jovanovic 1991.
11	Centre for International Economics, 1994, Prepared for SFNSW.	Community and social benefits of eucalypt plantations	NSW	*not-specified*	Descriptive costs and benefits	N/A	N/A	N/A	None	None	Descriptive summary of costs and benefits to community of eucalypt plantations.
12	Chandler, Fraser, Keating, Forest Industry consultants New Zealand, 1994, for SFNSW.	A eucalypt plantation programme for NSW	All NSW	*Unspecified eucalypt*	Approx royalty	N/A	N/A	Australian markets and international demand.	None	None	A market discussion

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13	Clark, R.V., 1995, SFNSW	Growing radiata pine sawlogs on farms in NSW. Plantations and agroforestry for profit.	NSW	*P.radiata*	Management regime	N/A	N/A	Costs of establishment, approximate returns, present values.	None	Soil depth 40-50 cm, < 18^{o} , most soils suitable except poorly drained or soils with poor water holding capacity	Guide to planning, assessment, maintenance and harvesting
14	Clark, J., 1995, Environment Victoria. A report to the State Conservation Councils.	Australia's Plantations: industry, employment, environment.	Australia	*P.radiata*	MAI for softwood plantation regions. Projected softwood timber production. National area of plantation by region	None	None	Overall industry overview, markets, current volumes, employment, growth potential.	None	None	An overview of the plantation based industry inc.: employment, industry potential, and resource.
15	Cornish, P., 1989, Technical Paper No. 49, FCNSW.	The effects of radiata pine plantation establishment and management on water yields and water quality - a review	Australia, New Zealand, South Africa	*P.radiata*, and mentioned eucalypt usage.	Changes in streamflow with plantation age, downstream impacts.	N/A	N/A	N/A	N/A	N/A	Review of plantation effect on water quantity and quality.
16	Crevatin et al 1996. Undertaken by DPI forestry for Queensland Commodity Exports	South – east Queensland hardwood plantation land suitability study	SEQ	No particular hardwood species	Annual precip ANUCLIM, slope AUSLIG Land cover Landsat, statigraphic units, cadastral	Freehold cleared land, rainfall, slopes, soil type classes	Land use (not used for cropping), land size, distance from Brisbane	N/A	N/A	N/A	Assessing feasibility of amount of land suitably available for plantations around the Port of Brisbane

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17	Dwyer Leslie Pty Ltd, in association with Corporate Impacts P/L and Dr R.A Powell, 1990-1991/Dwyer Leslie Pty Ltd, in association with Dr R.A Powell, 1993-1995/, FCNSW/ SFNSW	Oberon: Rural Community Development Study, Years 1 to 5 and Final Report.	Oberon, Central Highlands	*P.radiata*	Employment industry economics, multipliers	N/A	N/A	Economic benefit to community and government	Road haulage network	None	Social and economic impacts of Forest Plantation establishment in Oberon.
18	Eucalypt and Forestry Services, 1995, Armidale.	An economic appraisal of the environmental and social effects of eucalypt plantations establishment under the joint venture program of State Forests of NSW.	All NSW	Unspecified eucalypts		N/A	N/A	Economic benefits on state scale	N/A	N/A	Covers range of social, environmental, economic costs/benefits, inc., hydrological, edaphic.
19	Furrer, B., 1993, Forest Planning and Environment Series, Vol. 3, SFNSW.	Eucalypt plantations in NSW	All NSW	Unspecified eucalypts	Approximate yield tables	N/A	N/A	IRR's	None	N/A	Outlines assistance measures, benefits, IRR's, and opportunities in NSW.
20	Geddes Management 1998	Mt Lofty Ranges Farm Forestry Industry Plan	Mt Lofty SA	*P. radiata* *E. globulus,* *E. saligna* *C. maculata*	N/A	Cleared freehold land, rainfall, soils (fertility, water holding capacity), Slopes	Land use, property size Market potential, landholder attitudes	Socio-economic issues	N/A	N/A	A report of area statements and maps. Growth rate estimation

Ref No.	Author/ Date/Source	Title	Regions	Species	Data lists used	Capability	Suitability	Economic analysis	Maps used	Envelopes	Notes
21	James, R.N, Florence, R.G, Mahendra-rajah, S and Turner, B.T, 1995, report to the Standing Committee on Forestry, Fisheries and Aquaculture, Department of Forestry, ANU, Canberra.	Forest Plantations of Australia - Their role in providing current and future wood supplies.	Australia wide	Unspecified	Production and consump-tion figures for hardwood and softwood	Not considered	Not considered	N/A	None	Not discussed	Discusses area reported to replace native forests
22	Johnson, I.G. & Stanton, R.R., 1993 FCNSW Research Division, Research Paper No. 20.	Thirty years of eucalypt species & provenance trials in NSW. Survival & growth in trials established from 1961-1990.	All NSW	Various	Show growth rates	N/A	N/A	N/A	Location of trials	NA	Useful for growth data
23	Jurskis, V., 1996, SFNSW, Southern Research.	Plantation land suitability assessment - Southern Region	Southern region, South of Bowral	*P.radiata,* discussion of eucalypts	State Forest GIS	Rainfall, slope, cleared land. Secondary criteria of soil and site quality.	Some field checking of soil depth, and native vegetation.	No economic analysis attempted.	GIS maps produced showing potentially suitable land for softwood. 1:600 000	Annual mean rainfall INXS of 700mm pine 900mm eucalypts slopes<18^o Land essentially cleared secondary criteria, soil>1000mm , native veg^n >25m	Areas suitable for pine and eucalypt. Limitations include geology, detailed soil analysis, economics, species potential, and the coarse scale.

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24	Keenan, R. 1998. Undertaken by Queensland Forest Research Institute	Farm forestry in the tropics: potential and pitfalls (prelim on plantation potential)	Northern Queensland, above 1000 mm only	*P. caribaea var. hondurensis, A. cunninghamii and various Euc and rainforest sp.*	BIOCLIM	Cleared land, rainfall, slopes, climate	Distance from Cairns, land use (not used for high value agriculture or farming)	Distance from Cairns	Map of capable land for a number of species	N/A	Map of capable land for a number of species
25	Lancefield Consultants, 1995	Farm Forestry Strategy Task Force Consultancy Report	SW WA	*P. radiata, E. globulus, P. pinaster*	MAIs,	Cleared freehold land, rainfall, soils, growth rates	Distance to centre	IRRs	Blue gum potential map	Rainfall >450mm/yr for pinaster, >600mm/yr for other sp.	Area statements by regional groups
26	Landsberg, J.J., Jones, P.M. and Pryor, L.D., 1990, Report on a study undertaken for the Common-wealth Minister for Resources.	Development of a plantation strategy for the south-east forests of NSW.	SE NSW	*E.nitens E.grandis E.saligna E.globulus* others discussed	MAI for various eucalypts in varying areas economic analysis, inc RoR.	Lithography, rainfall	Doesn't account for land costs.	RoR's for varying yields and rotations based on establishment and maintenance costs.	None published	Rainfall 850-900mm rainfall 650-850mm rainfall>900mm slopes <15^o rateable land	Provides area based on capability, includes approx MAI's, doesn't include land value
27	Bonny, L, 1991, FCNSW, Research Paper No. 12.	Growth of an *E. grandis* plantation following intensive silvicultural treatments applied in the first six years.	Coffs Harbour	E. grandis	Provides MAI & CAI curves	N/A	N/A	None	None	N/A	Provides idea of growth rates with differing treatments.
28	Lewis, N. B and Ferguson, I.S., 1993.	Management of radiata pine.	Australia, New Zealand, Chile, South Africa	P.radiata	Growth and yield curves	N/A	N/A	Descriptive not specific	None	General requirements of radiata pine	Comprehensive book covering all aspects of radiata pine management

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29	Lindenmeyer, Mackay, Nix, 1996, Aust For. 59 p74-89.	The bioclimatic domains of four species of commercially important eucalypts from South-Eastern Australia.	SE Aust	*E.regnans* *E.delegatensis* *E.fastigata* *E.nitens*	Bioclim Analysis for each species EUCALIST used for data source.	Elevation, rainfall, distribution, temp range and seasonal changes.	N/A	None	Very small scale potential maps	Elevation, rainfall, temperature.	Uses natural ranges of species and climatic requirements, matching them with bioclim analysis.
30	Maclaren, J.P., 1993, FRI bulletin No. 184 NZ Forest Research Institute.	Radiata pine growers manual.	New Zealand	*P.radiata*	N/A	N/A	N/A	Basic analysis	None	Site selection requirements	An excellent non-technical practitioners guide on all aspects of radiata pine
31	Margules Groome Pöyry and Macquarie Corporate Finance, 1996, prepared for SFNSW.	Investor participation mechanisms in hardwood plantations in NSW	NSW	Unspecified hardwood	Investor mechanism	N/A	N/A	Capacity to pay calculations for pulpwood	None	None	Discusses potential investment in plantations and impediments
32	Margules Groome Pöyry Ltd Australia, DIST, DPIE, 1995.	Australian plantation bench-marking study.	National	N/A	Economic costs	N/A	None	Investor types, supply & demand factors, markets, government constraints. Minimum required IRR. Sources of information relating to forestry investment. International Land costs, prices, harvest & transport	None	None	Describes Australia's plantations industry, economics & industry locations.

Ref No.	Author/ Date/Source	Title	Regions	Species	Data lists used	Capability	Suitability	Economic analysis	Maps used	Envelopes	Notes
33	Margules Groome Pöyry Ltd, 1993, prepared for Softwoods Working Party.	State softwoods strategic plan for NSW (draft)	All NSW	*P.radiata*	Markets, and potential, general management regime	N/A	N/A	Markets, and supply commitments	N/A	N/A	Discusses supply/demand, markets, constraints, environmental issues and proposes strategy.
34	Margules Pöyry 1998. Prepared for Plantations North East	Regional Profile of North East Victoria	NE Vic	*P. radiata, E. globulus*	Large variety	Climate, soils, slope, growth rates	Tenure, land prices, infrastructure industry location,	Infrastructure, industry location, financial returns	Location of LGA, infrastructu re, rainfall, tenure, current plantations radiata suitable land, blue gum suitable land, opp zones, wood vol, industry locations	N/A	It identifies areas within NE Vic that are physically suitable for plantation expansion using a combination of industrial and market information, and physical conditions
35	Margules Pöyry 1997. Prepared for Greening Australia & NT Forestry and Timber Products Network	Feasibility study – Farm forestry in the top end of the NT	Northern Territory	Various	Using existing information and GIS data	Temperature, rainfall, soils	Land size, land use, utilities, port infrastructure market demand	Financial analysis		N/A	Feasibility report for farm forestry in NT

Ref No.	Author/ Date/Source	Title	Regions	Species	Data lists used	Capability	Suitability	Economic analysis	Maps used	Envelopes	Notes
36	Meynink, R., 1990, prepared for Harris-Daishowa (Australia) Pty.Ltd.	An analysis of the Landsberg, Jones, Pryor 1990 "Develop-ment of a plantation strategy for the South-East Forests of NSW" report.	SE NSW	*Not specified*	Looks at haul distances, harvest costs, mill costs, MAI, land costs establish-ment and maintenance costs to determine IRR for plantations.	N/A	N/A	Detailed look at costs and IRR for varying land costs	None	Parameters for IRR	Reviews Landsberg report and provides economic analysis including land costs.
37	Mousa, A, And Keady E. July 1996, Resources Branch Department of Primary Industries, Queensland	plantation volume growth summaries from growth plots in Queensland	QLD	*Hoop pine, slash pine, radiata pine, Pinus taeda, Pinus patula, Pinus caribaea*	growth rates	not specified	not specified	N/A	9	not specified	growth summaries
38	Northern NSW Forestry Services, 1994, Study undertaken for the Mid North Coast Regional Development Board.	North Coast Forest and Plantation Resource Study.	North Coast NSW	*E.pilularis E.grandis E.saligna E.nitens*	Limited approx MAI for flooded gum and Blackbutt. Existing, and potential areas of hardwood plantations	Climatic and edaphic requirements	Includes some consideration of land value and survey of landowners	Develops IRR's for varying land costs, including establishment costs, and annual costs	Identifies broad areas as having the best potential.	Temp, rainfall, soil types, dry season length	Comprehensive look at hardwood potential and existing resource in N NSW. Potential areas based on landowners surveys, not capability criteria.

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39	Northern NSW Forestry Services, SFNSW, 1996, Study undertaken for the Mid North Coast Regional Development Board.	Mid-north Coast Forest and Plantation Resource study.	Mid North Coast NSW	*E.pilularis* *E.grandis* *E.agglomerata* *E.nitens* *E.saligna* *E.maculata* *E.dunnii* *E.laevopinea* *E.cloeziana*	Potentially suitable plantation area by local government area. Used (unspecified) GIS analysis Existing plantations Net Productive areas by forest type	Climate, soil, land tenure,	Excluded prime land for horticulture, steep slopes, uncleared land	Profitability based on costs, MAI and land costs.	1:600 000 maps. Includes existing and potential areas	>900mm, cleared private land, non-prime ag land, <18^{o} 10-20 hectares minimum size, well drained soils, access	Comprehensive analysis of region, including existing and potential, and covering economics. Does not cover exact CRA region, will be a good cross reference.
40	O'Hara,A.J., 1990, FCNSW, paper to Austis Conference, Tasmania.	Economics of growing eucalypt sawlogs in plantations.	NSW	Non-specific	Predominantly an economic analysis, includes basic yield tables	N/A	N/A	Detailed economic analysis based on establishment and management costs, returns, MAI, and sensitivity analysis.	None	N/A	Economic analysis looking at variables, and potential IRR. Not considering potential.
41	Private Forestry Tasmania farm forestry project	Tasmanian RFA background report Part D Social and Economic Report Vol II	Tasmania	*P. radiata,* *E. globulus* *E. nitens*	N/A	Cleared freehold land, rainfall, temperature, soils, productivity classes	Socio-economic study	Socio-economic study	N/A	N/A	Prepared as part of the CRA/RFA process
42	Prosser, M., 1989, Honours thesis ANU Canberra.	The economics of eucalypt plantations- a case study: Blackbutt plantations of the New South Wales north coast.	Northern NSW	*E.pilularis*	MAI Blackbutt	Climate, soil, very basic analysis.	Cleared land, <120km from major town but >10km	Costs and returns	Unscaled map used for areas available	Cleared land, <120km from major town but >10km	Basic look at available areas, more detail on costings and economics.

Ref No.	Author/ Date/Source	Title	Regions	Species	Data lists used	Capability	Suitability	Economic analysis	Maps used	Envelopes	Notes
43	Queensland RFA S/C 1998	Commercial plantation land suitability analysis of SE Queensland	SEQ	*Araucaria cunninghamii, P. elliottii x P. caribaea, E. argophloia, C. maculata E. pilularis, E. cloeziana E. grandis*	Climatic modelling	Cleared land Slopes, soil capability classes, climate, rainfall	N/A	N/A	N/A	Slopes <30º	Area statement and maps
44	Regional Analysis and strategies - prepared for SFNSW by Regional Analysis and Strategies, Armidale 1994	The impact of eucalypt forestry on the NSW economy	All NSW	Non-specific	Approximate prices for products	N/A	N/A.	State wide economic benefits.	None	None	Looks at economic benefits of a increase in NSW plantation estate
45	Reilly, J.J., Parkes, E.D., and Ferguson, I.S., 1975, Aust For. 37 p233-44.	The potential productivity of farmlands in the lower south coast region of NSW for radiata pine plantations.	Lower South coast NSW	*P.radiata*	Site index for *P.radiata* for various ages/areas. Approx areas suitable by district.	Land category determined by: soils, topography, geology. Site index by rainfall.	Not considered	Not considered	N/A	N/A	A report looking at categorising farmland potential for *P.radiata*
46	Report of the National Plantations Advisory Committee. 1991	Integrating farming and forestry. Commercial wood production on cleared agricultural land. Appendix C. "Economics on farm forestry enterprises: a study approach"	All Australia	*E.diversicolor E.globulus E.grandis E.nitens E.pilularis E.regnans E.saligna A.mangium A.mearnsii A.melanoxylon P.radiata P.elliottii P.caribaea Araucaria cunninghamii*	N/A	Potential for hardwood on cleared land	Discusses economics	Tas, Vic, WA case studies. Costs and returns for farming and forestry.	N/A	Discusses farm conditions.	Analysis of plantation economics based on a number of case studies.

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47	Furrer, B, 1994, SFNSW.	Eucalypt plantation joint venture site selection.	NSW	Various eucalypts	None	Growth capacity to achieve 20m^3/ha/yr aim over 20 years. Economic capability	N/A	Specifications for obtaining timber with growing costs <$20/m^3 after 20 years	Small scale suitability class map and rainfall map.	<18^o 1m soil >100ppm total P rainfall>900mm <20% crown cover >25m dominant height	Outlines requirements for selection for joint venture program.
48	Centre for International Economics, 1994, prepared for SFNSW.	Community and social benefits of eucalypt plantations.	NSW	None	None	N/A	Talks about competing requirements for water	None	None	None	A very brief coverage of social benefits
49	SFNSW 1996	SFNSW Northern Region Softwoods Strategy, 1996	N NSW	*P.radiata*	National/ international supply/demand status MAI for varying areas	N/A	N/A	N/A	N/A	N/A	Predominantly a market analysis and outlining objectives and strategies for the Northern region softwoods
50	SFNSW, 1996	Land Potentially Suitable for Eucalypt Plantation - North Coast of NSW	North Coast NSW	*E.pilularis, E.maculata, E.dunnii*	Area statements, State Forest supply zones, management and harvesting schedules	Rainfall, soils, Land and Water Conservation capability classes	Looks at supply zones and distances to markets	Not analysed	SFNSW GIS produced map showing suitable areas	900 mm rainfall, cleared land, < 18^o slope, exclude prime agricultural land, west of Pacific Hwy., < in 700 m except Dorrigo	A very brief outline of methods used to determine areas suitable.

Ref No.	Author/ Date/Source	Title	Regions	Species	Data lists used	Capability	Suitability	Economic analysis	Maps used	Envelopes	Notes
51	SFNSW, 1997	hardwood plantation strategic plan 1997/98	NSW	*E.pilularis, E.maculata, E.dunnii E.grandis*	area statements of current plantations, area summary by site class	area summary by site class,	area summary by supply zone,	financial overview, environmental and social benefits and costs	land potentially suitable for eucalypt plantations 1:700 000	900 mm rainfall, cleared land, < 18^{o} slope, exclude prime agricultural land, west of Pacific Hwy., < in 700 m except Dorrigo	An analysis of plan of action to establish 10 000 hectares of eucalypt plantations in 1997/98. Also outlines plan to establish 10 000 ha in 1998/99 and 10 000 hectares in 1999/2000.
52	SFNSW 1997 Central Tablelands Farm Forestry Project	An evaluation of forestry land capability for *Pinus radiata* in the Central Tablelands, NSW	Central Tableland of NSW	*P. radiata*	ESOCLIM, soil landscape sheets	Private cleared land Rainfall classes	Distance to markets	Distance to markets	Rainfall, soils, capability, suitability	700-850 mm rainfall	Area statements and maps for Central Highlands (Bathurst/Oberon)
53	SFNSW & DLWC, 1997.	Erosion & sediment control strategy for eucalypt plantation establishment on the North Coast of NSW.	NE NSW	Eucalypts	Environ-mental constraints	N/A	N/A	N/A	N/A	N/A	Covers legislation, and environmental controls
54	Shea & Hewett, 1997 undertaken by CALM	*Pinus pinaster* project	SW WA	*P. pinaster*	GIS analysis	Rainfall, non waterlogged & non-saline soils	N/A	Discussion of socio-economic issues	Land availability for *P. pinaster*	400-600 mm rainfall	Looks at potential of *P. pinaster* in the intermediate rainfall areas of the state
55	South East Forest Foundation 1996	Esperance regional development strategy for farm forestry	SW WA, Esperance	*E. globulus, P. pinaster*		Cleared freehold land, soils, temperature	Distance to centres, land use, land acquisition strategies		Rainfall & soil types	Rainfall > 450mm	Area statements, Results of early growth plots

Ref No.	Author/ Date/Source	Title	Regions	Species	Data lists used	Capability	Suitability	Economic analysis	Maps used	Envelopes	Notes
56	Spencer R.D. et al., 1999 undertaken by BRS & ABARE	Opportunities for hardwood plantation development in South East Queensland	SEQ	*E. pilularis, E. cloeziana, Corymbia citriodora, E. grandis*	AAGIS, ADIS, GRO	Soils, slope, rainfall	Land prices, private cleared land	Plantation yields, plantation costs & returns, land prices	Plantation capability, sawlog regimes (NPV), NPV as % of land value, highest economic suitability, sawmill allocation zones	Rainfall b/n 800-1000mm p/a for spotted gum. Rainfall over 1000mm p.a. for blackbutt, Gympie messmate, and rose gum	Plantation capability modelling for SEQ region, producing area statements and maps of potential areas for each species
57	Stanton, R., 1992, Research Paper No. 15 FCNSW.	Eucalyptus plantations in NSW	All NSW	Varied	NSW plantation areas to 1992	N/A	N/A	Not considered	Location of manageme nt areas	N/A	Description of NSW plantation estate to 1992.
58	Stanton, R.R.J., 1990, Honours thesis, ANU, Canberra.	Land evaluations for eucalypt plantation purposes in the south-east region of NSW.	SE NSW	*E.agglomerata E.fastigata E.globulus E.nitens E.sieberi*	Basic species requirements.	Elevation, slope, total rain, seasonality, nutrient supply.	Divides into 4 classes	None	BIOCLIM GETCLIM SLPGRD (aspect) GRDAREA (area calculation)	Rainfall>850 mm where <600m elevation rainfall >750mm where >600m elevation slopes <15^o potential nutrient supply index >5 out of 10	Honours thesis using GIS and base environmental attributes to determine area available for plantations.

Ref No.	Author/ Date/Source	Title	Regions	Species	Data lists used	Capability	Suitability	Economic analysis	Maps used	Envelopes	Notes
59	Stephens, N., Sun, D., and Tickle, P., 1998. Bureau of Rural Sciences	Plantation potential studies in Australia: an assessment of current status	All regions	*16 Eucalyptus sp., 3 Corymbia sp 5 Pinus sp. Acacia melanoxylon, Casuarina cunninghamiana, Grevillea robusta, Araucaria cunninghamii, Toona ciliata, Flindersia spp*	Questionnaire survey, literature review.	Rainfall, soil, geology attributes, temperature, altitude, slope. It varies depending which study was looked at.	Land size, land use, distance to mills, community attitudes. It varies depending which study was looked at.	socio-economic analysis, market potential, distance to mills, NPV, port infrastructure, market demand, financial analysis, impacts of legislation and scenario modelling. It varies depending which study was looked at.	N/A	N/A	A literature review undertaken on published studies relating to the identification of capable, suitable and available land for plantation development.
60	STFFN – Southern Tablelands Farm Forestry Network (1997) Kim Wells	Potential for commerical farm forestry on the NSW Southern Tablelands	Southern Tablelands NSW	*P. radiata*	Soil landscapes – topography & soils	Soil landscapes – topography & soils	N/A	Market potential based on a pers. Comm.	N/A	Excludes: <550mm rainfall, <50cm soil depth, >29 degrees slope	A very brief summary
61	Wareing K and Baker R. 1998. Prepared by BRS under the NE Vic RFA process	Opportunities for plantation expansion in the Victorian NE CRA/RFA region	NE Vic	*E. globulus, P. radiata*		N/A	Land value, land use, parcel size, farmers perceptions to farm forestry, community concerns	Scenario modelling	N/A	N/A	A report of area statements and maps
62	Wilson, S.M. Whitlam, JAH Bhati, U.N. Horvath, D Tran, U.D., ABARE 1996 Research Report 95.7.	Trees on Farms. Survey of trees on Australian farms 1993-1994.	National	Various	N/A	N/A	N/A	N/A	N/A	N/A	An overall outlook on farmers perceptions, costs & benefits & reasons for planting.

APPENDIX 2 - DATA REQUIRED

Data Required	Existing Data	Data Gaps/Action
High resolution digital elevation model (DEM) of 100m resolution or better, preferable 25-50m Attributes: - elevation - slope - aspect - position in slope - compound topographic index	Area is covered by existing DEM from LIC with the exception of 15 x 1:100,000 map sheets that lie outside the CRA regions. The area covered by these map sheets are Manilla, Bathurst and Orange.	The areas without DEM are important areas for plantations and would be required for context for CRA analysis. There may be a need to generate DEM for these map sheets from contour and stream data, depending on the LIC production timetable and the project's time requirements. BRS is in a position to do the processing as required as part of the task. Discussions are under way with LIC to fill gaps.
ESOCLIM climatic modelling data layers including: - mean monthly evaporation - radiation (surface, corrected for slope and aspect) - mean annual rainfall - rainfall seasonality (summer, winter, bimodal etc.) - length of dry season (if appropriate) - mean maximum temperature of the hottest month - mean minimum temperature of the coolest month - mean annual temperature - absolute minimum temperature	- Eden - Joint Scientific Committee - Eden Management Area Environmental Impact Statement, November 1994	Data gaps include previous use of coarse DEMs and the need to improve radiation data. BRS are in contact with NPWS. BRS will use 100 m DEM scale, generate climate layers and provide work to NPWS.

Data Required	Existing Data	Data Gaps/Action
Soils and/or geology layers	As part of the Site Productivity Index Eden FRAMES project, CSIRO will compile suitable GIS layers on lithology, potential nutrients and erodibility which can be used to input into the Eden plantations project. Digital soil landscape mapping is available for some areas of the state from DLWC. Soil sample information is available from DLWC's NSW Soil Data System. SFNSW GIS holds various (e.g. DLWC, SFNSW) soil landscape mapping information and geology layers.	Due to new and improved mapping and new and other data, BRS have contracted the CSIRO to refine geochemical data for the Site Productivity Index Eden FRAMES project. In particular, the sedimentary areas are being tightened up. It is expected that for most regions where soil mapping does not exist, soil properties will have to be derived from other sources such as: landscape mapping, geology and geochemical mapping and terrain data, DLWC's NSW Soil Data System. Audit of NSW Department of Mines mapping underway. Soil landscape mapping will be used where available.
DLWC land capability classification	Digital land capability classification layers available from DLWC	No data gaps
Existing plantation location	- SFNSW data bases/GIS - National Plantation Inventory	No data gaps identified, although SFNSW hardwood data base is still being finalised.
Woody vegetation layer	- NPWS Eastern Bushland Database - Information currently being compiled for other CRA assessment projects	The NPWS Eastern Bushland Database uses a manual interpretation of Landsat whereas the latest data being compiled is digital and of a higher resolution. Being compiled by LIC using 1991 Landsat TM imagery along the entire coastal and escarpment areas of NSW to abut the already completed tablelands and slopes. Timelines for completion extend into late 1997. BRS is in a position to update (and accelerate where necessary) this coverage using 1996 Landsat TM images already purchased. NSW NPWS will complete woody vegetation mapping (mid April 1997) of Eden as part of another CRA project.
Cadastre (or at least exclusion of existing State forest, National Park and other Crown lands)	LIC/SFNSW GIS holds this information	No data gaps identified. No further action required.
Land value for high capability areas	This information does not presently exist.	To be generated using information from Valuer General's office, municipal councils, commercial estate agents and SFNSW knowledge/data.

Data Required	Existing Data	Data Gaps/Action
Cultural landcover (for exclusion of urban and other developed land)	See below	Currency of information will be checked on a region by region basis using satellite imagery.
Infrastructure (roads, processing plants etc)	Processing facilities available from ABARE. BRS holds AUSLIG 1:250,000 scale road networks SFNSW holds 1:25,000, 1:50,000 and 1:100,000 LIC information for some areas, SFNSW roads data held at 1:25,000.	Currency of infrastructure information will be checked on a region by region basis.
SFNSW existing plantation inventory data	SFNSW yield data	No data gaps identified. No further action required
Economic and market assessment	- ABARE's industry outlook part of "the profile of forests uses (including softwoods) project" - marketing input from SFNSW - ABARE's project on wood industry development opportunities (SFNSW database of cost structure and benchmarked comparisons together with market price predictions for various species and product combinations, recent reports by BIS Schrapnel and Ausnewz) - ANZEF report - Margules report - Economic RFA assessments - Nielsen reports	Little work done - expert consultation required to develop and refine methods.
Impact on regional economies and social development	- Oberon Rural Community Development project commissioned by SFNSW - the RAC findings - EIS work - ABARE FORUM model - social RFA assessments	Existing and current studies to be drawn upon for this project.
Water Quality and Quantity	- SFNSW research (e.g. Cornish, P.M, 1989, *The effects of radiata pine plantation establishment and management on water yields and water quality - a review*. Technical Paper No. 49, FCNSW)	Expert consultation required to develop methods for this project.
Pollution Controls	- SFNSW Pollution Control Licenses - Standard Erosion Mitigation Guidelines for Logging in NSW - Erosion and Sedimentation Control Strategy for Eucalypt Plantation Establishment on the North Coast of NSW, May 1997	No further action required.

Data Required	Existing Data	Data Gaps/Action
Management Constraints	-State Environmental Planning Policy No 46 - Protection and Management of Native Vegetation - Conservation protocols for timber harvesting on State Forest for the duration of the IFA Decision, NPWS, SFNSW, 29 November 1996 - SFNSW Codes of Practice (Timber Harvesting in State Forest Plantations, Plantation Establishment and Maintenance, Road and Trail Maintenance (draft)) - Code of Practice for Forest Plantations on Private Land in the South-West Slopes of NSW, Australian Forest Growers - Relevant NSW environmental legislation (e.g. Environmental Planning and Assessment Act, 1979; Local Government Act, 1979; National Parks and Wildlife Act, 1974; Threatened Species Conservation Act, 1995; Clean Waters Act, 1970; Environmental and Offences and Penalties Act, 1979; Pollution Control Act, 1970; Soil Conservation Act, 1938; Heritage Act, 1977; Bush Fires Act, 1977; Forestry Act, 1916; Timber Plantations (Harvest Guarantee) Act, 1995, Noxious Weeds Act, 1993; Pesticides Act, 1978; Rural lands Protection Act, 1983 etc)	No further action required.

APPENDIX 3 - SUMMARY STATISTICS FOR CLIMATE SURFACES BY PRODUCTIVITY CLASS

Hardwood species productivity classes and values of rainfall and temperature.

Total Annual Rainfall (mm) :	min	mean	max	std
Incapable	527	871	2270	217
Low potential	900	1140	3220	184
Medium potential	900	1243	3162	213
High potential	901	1464	2868	275

Maximum temperature (mean of 12 months, degrees C) :	min	mean	max	std
Incapable	13.2	20.5	25.4	2.4
Low potential	15.5	22.7	26.5	2.1
Medium potential	16.8	23.3	26.5	1.3
High potential	18.2	23.5	26.0	1.1

Maximum temperature (max of 12 months, degrees C) :	min	mean	max	std
Incapable	20.2	26.5	32.6	2.3
Low potential	21.7	27.5	31.4	1.7
Medium potential	22.7	27.7	30.9	1.0
High potential	23.2	27.6	30.3	0.9

Minimum temperature (mean of 12 months, degrees C) :	min	mean	max	std
Incapable	3.8	7.9	15.0	1.9
Low potential	5.9	10.7	15.0	2.0
Medium potential	6.5	11.9	15.0	1.2
High potential	8.2	12.7	15.0	1.0

Minimum temperature (min of 12 months, degrees C) :	min	mean	max	std
Incapable	-3.6	0.8	8.8	2.0
Low potential	0.0	3.8	8.8	2.2
Medium potential	0.0	5.4	8.8	1.3
High potential	1.8	6.4	9.6	1.1

Pinus elliottii productivity classes and values of rainfall and temperature.

Total Annual Rainfall (mm) :	min	mean	max	std
Incapable	527	871	2270	217
Low potential	900	1171	1890	166
Medium potential	900	1141	2536	192
High potential	900	1383	3220	260

Maximum temperature (mean of 12 months, degrees C) :	min	mean	max	std
Incapable	13.2	20.5	25.4	2.4
Low potential	20.4	24.7	26.5	0.9
Medium potential	16.2	22.8	26.5	1.7
High potential	15.5	22.7	25.7	1.6

Maximum temperature (max of 12 months, degrees C) :	min	mean	max	std
Incapable	20.2	26.5	32.6	2.3
Low potential	26.0	29.0	30.9	1.1
Medium potential	22.4	27.6	31.4	1.4
High potential	21.7	27.0	29.8	1.2

Minimum temperature (mean of 12 months, degrees C) :	min	mean	max	std
Incapable	3.8	7.9	15.0	1.9
Low potential	7.3	12.7	14.8	1.2
Medium potential	6.0	10.9	15.0	1.9
High potential	5.9	11.8	15.0	1.7

Minimum temperature (min of 12 months, degrees C) :	min	mean	max	std
Incapable	-3.6	0.8	8.8	2.0
Low potential	0.0	5.7	8.5	1.6
Medium potential	0.0	4.1	8.8	2.1
High potential	0.0	5.5	9.6	1.9

Araucaria Cunninghamii productivity classes and values of rainfall and temperature.

Total Annual Rainfall (mm) :	min	mean	max	std
Incapable	527	871	2270	217
Low potential	900	1080	1890	142
Medium potential	900	1183	2466	169
High potential	911	1476	3220	261

Maximum temperature (mean of 12 months, degrees C) :	min	mean	max	std
Incapable	13.2	20.5	25.4	2.4
Low potential	16.6	24.0	26.5	1.5
Medium potential	16.0	22.6	26.0	1.7
High potential	15.5	22.7	25.7	1.6

Maximum temperature (max of 12 months, degrees C) :	min	mean	max	std
Incapable	20.2	26.5	32.6	2.3
Low potential	22.8	28.6	31.4	1.1
Medium potential	22.1	27.2	30.4	1.3
High potential	21.7	27.0	29.8	1.2

Minimum temperature (mean of 12 months, degrees C) :	min	mean	max	std
Incapable	3.8	7.9	15.0	1.9
Low potential	6.2	11.7	14.8	1.7
Medium potential	6.0	11.0	15.0	1.9
High potential	5.9	11.9	15.0	1.8

Minimum temperature (min of 12 months, degrees C) :	min	mean	max	std
Incapable	-3.6	0.8	8.8	2.0
Low potential	0.0	4.7	8.5	1.9
Medium potential	0.0	4.3	8.8	2.1
High potential	0.0	5.6	9.6	1.9

APPENDIX 4 - SPECIES REQUIREMENTS

Species	Natural range	Mean annual rainfall (mm)	Rainfall regime	Dry season length (<40mm/ month)	Mean maximum temperature of hottest month (°C)	Mean minimum temperature (°C)	Mean annual temperature (°C)	Optimal Soil Requirements	Growth MAI (m^3/ha/yr)	Potential problems
E.grandis	E coast	800-2500	summer	0-5	25-34	3-16	14-25	deep well drained	NA	Christmas beetles, chrysomelid beetle, psyllids
E.pilularis	E coast	750-2000	summer/ uniform	0-2	22-31	5-12	15-22	sandy loams	20m3/ha/year in QLD	susceptibility to root rots
P.elliottii x caribaea	E coast	750-1700	summer	0-5	26.5-31	5-12.5	18-23		NA	minimal pests
Araucaria cunninghamii	E coast	900-2300	summer	0-2	27-34	4-18	17-26	Deep, moist, well drained	NA	Pine bark weevil ambrosia bark beetle

Species requirements as provided in Appendix B “Integrating forestry and farming” Booth and Jovanovic 1991

APPENDIX 5: ASSUMED COSTS AND MARKET PRICES

Cost	value	unit
Hardwood Current		
- Establishment	$2,300	/ha
- Post establishment	$600	/ha
- Maintenance	$160	/ha/yr
Hardwood Target		
- Establishment	$2,000	/ha
- Maintenance	$90	/ha/yr
Softwood (*P. elliottii*)		
- Establishment	$1,400	/ha
- Post establishment	$300	/ha
- Maintenance	$40	/ha/yr
Softwood (*A. cunninghamii*)		
- Establishment	$1,800	/ha
- Post establishment	$200	/ha
- Maintenance	$40	/ha/yr
- Pruning (yr 9,11)	$350,$500	/ha
Road Construction (prior to 1st thin)	$300	/ha
Marking (each thin)	$100	/ha
Transport - sealed roads	$0.09	/m^3/km
Transport - unsealed roads	$0.11	/m^3/km
Harvest	$18	/m^3
Stumpage Prices (base)		
Softwood sawlog thins/Hardwood HQS sawlogs	$25	/m^3
Softwood sawlog clearfell/ Hardwood HQL sawlogs	$50	/m^3
Pulplogs	$15	/m^3
Stumpage Prices (high price)		
Softwood sawlog thins/Hardwood HQS sawlogs	$27.50	/m^3
Softwood sawlog clearfell/ Hardwood HQL sawlogs	$55	/m^3
Pulplogs	$16.50	/m^3

APPENDIX 6 YIELD TABLES FOR HARDWOOD SPECIES IN NORTHERN NSW

Two yield tables are provided for the analysis of hardwood plantation production for Northern NSW. Table 1 was developed at BRS using assumptions produced through Turland (1998). The assumption agreed below for both the distribution between product classes and thinning regime adopted. The BRS model is conservative especially regarding the MAI assumptions but this realistically matches early SFNSW plantings. With improvements in technique and seedling stock higher MAI predictions are reasonable. The thinning regime matches conventional plantation silvicultural theory in the intensity and method of thinning.

Table 2 shows the PYP model produced by West (1999). This model uses higher MAI and a very aggressive thinning regime. The adoption of the two sets of tables allows comparison using varying assumptions and a more broad result range for outlining possible outcomes.

Table 1: Yield table Northern NSW Conservative Model

Class	Initial stock	T1 age	T1 Stock	PULP	T2 age	T2 Stock	HQLSL	HQSSL	pulp	Clearfell	HQLSL	HQSSL	PULP	MAI m³/ha/yr	total vol m³
1	1000	15	500	74	25	250	9	27	54	40	139	41	136	12	480
2	1000	15	500	92	25	250	23	34	57	35	160	58	102	15	525
3	1000	10	500	74	20	250	23	34	57	30	190	49	120	18	540

Assumptions

first thinning: minimum volume requirement of 70m3/ha, 5th row outrow, thin between bays
Second thinning:10 years after first thinning, minimum volume 70m3/ha, Class 1- ratio 1:3:6 Class 2,3 - ratio 2:3:5 large: small: pulp
Ratios based on West 1998 Yield management of Corymbia and eucalypt plantations
Clearfell 40: ratio Class 1 44:13:43 large: small: pulp
Clearfell 35: ratio Class 2 50:18:32 large: small: pulp
Clearfell 30: ratio Class 3 54:14:32 large: small: pulp
HQLSL should be split into HQLSL and Veneer logs at ratio 1:4 (veneer 80% of HQLSL product)

Table 2: Yield table Northern NSW using PYP SFNSW model

Species	Initial stock	T1 age	T1 Stock	HQLSL	HQSSL	Pulp	T2 age	T2 Stock	Veneer	HQLSL	HQSSL	pulp	CF age	veneer	HQLSL	HQSSL	pulp	MAI	total m³
Spotted Gum	800	14	250	2	17	93	20	90	19	15	29	31	34	260	5	12	7	15	490
Blackbutt	800	14	250	2	24	96	20	90	13	16	32	35	34	333	11	18	12	18	592
Flooded Gum	800	10	326	1	19	83							22	128	64	90	79	22	464

APPENDIX 7 SOFTWOOD YIELD TABLES FOR NORTHERN NSW

Hoop pine HIGH productivity - indicative MAI at full rotation of 25 m^3/ha/year

Operation	Age	Sawlog/Veneer Yield
T1	25	100
T2	30	100
T3	35	155
T4	40	180
Clearfell	45	595
Total		1130 (MAI 25)

Elliottii LOW productivity - indicative MAI at full rotation of 8-10 m^3/ha/year

Operation	Age	Sawlog-Veneer/Pulp Yield
T1	17	50/20
T2	22	70/10
Clearfell	39	190/10
Total		350 (MAI 9)

Elliottii MED productivity - indicative MAI at full rotation of 14.66 m^3/ha/year

Operation	Age	Sawlog-Veneer/Pulp (m^3/ha)
T1	16	70/20
T2	22	90/10
Clearfell	30	190/10
Total		350/40 (MAI 14.66)

Elliottii HIGH productivity - indicative MAI at full rotation of 20 m^3/ha/year

Operation	Age	Sawlog-veneer/Pulp
T1	14	75/25
T2	21	95/15
Clearfell	30	360/30
Total		530/70 (MAI 20)

APPENDIX 8 QUANTITATIVE ANALYSIS FOR ASSESSMENT OF NEW PLANTATION RESOURCE

A SFNSW inventory program has been developed for all new plantations to provide joint venture partners with feedback on their plantations performance, identify areas of poorly performing growth, and collect data for model development and improvement. The inventory consists of several integrated components:

- Rapid coupe assessments are undertaken in years 2 and 3 as a means of collecting early growth data. Plots are subjectively placed to represent areas of uniform growth as a means of preliminary stratification. Stratification aims to differentiate forest on species, survival, growth etc. Plot size is 0.02 hectares and aims to capture 18 trees/plot. Sample intensity's one plot per 3 hectares to a maximum of 25 plot per block/stratum. Data are stored and analysed in MARVL (Method of Assessment of Recoverable Volume by Log Grades).
- Routine inventories are conducted in year 5, immediately before and after thinning and prior to final harvest. The forest is *a priori* stratified from the rapid coupe data and plots are randomly placed on a grid at one plot per 4 hectares to a maximum of 25 plots per block/stratum. The inventory is designed to provide a 95 per cent confidence interval equivalent to 15-20 per cent of the sample mean. Data are stored and analysed in MARVL.
- Permanent sample plots are established in the first year if possible and randomly located in stands selected on a weighted random method where probability of selection is proportional to area. Measurements are taken annually to five years and then every second year thereafter. Plot size is 0.1 hectares.
- Taper and volume data are collected opportunistically in post 1994 plantations. To date, approximately 25 out of a target sample size of >100 trees have been measured.
- Carbon sequestration data are collected via a destructive sampling program (Cowie and Montagu 1999). The program is designed to quantify the relationship between diameter at breast height and biomass of canopy, roots and understorey. Soil organic carbon is also assayed. Fourteen to twenty trees are selected annually from a single species/age class to represent the range of diameters expected over a five year period. This allows for rotational sampling between the four principal species, returning to the original site every fifth year.

State Forests has developed an empirical yield model called Plantation Yield Predictor (PYP) for predicting growth and product yield for the four principal commercial species *Eucalyptus grandis*, *E. pilularis*, *E. dunnii* and *Corymbia variegata* (West 1998). The model was constructed from data drawn from SFNSW experiments, inventory and a national collection of regrowth and plantation eucalypt data by Mattay and West (1994), appropriately screened for abnormal growth and stand characteristics. The final data set was drawn from 1 608 measurements of 302 plots across the north coast of NSW and SE Qld.

The base input parameters for the model are site index (height of 40 tallest trees at 20 years) and stocking, and accommodates thinning and final harvest at various ages. Yield by product expressed as size class can also be specified. PYP has been modified to include carbon yield based on Knott's (1996) algorithms, and provides discounted cash flows to produce an internal rate of return for the forest investment (West 1998b). PYP is used for estate level strategic yield scheduling, and its growth curves have been incorporated into MARVL for block/strata level yield forecasting. Generic yield management schedules have been developed for thinning and pruning (West 1998c, 1999b).

Empirical models are reliable only for areas and species representative of the underlying data, and consequently, attempts have been made to construct a model capable of predicting growth on new areas and for hitherto uncommercial species. This has been driven by the ability to access areas of private land not previously available through the joint venture program, as well as land rehabilitation and carbon sequestration opportunities in the Hunter Valley and Western Slopes. A physiological model known as ProMod was calibrated from Battaglia and Sands (1997) for *E. grandis, E. pilularis, E. dunnii* and *Corymbia variegata*. In testing ProMods performance on advanced-age data from the pre 1994 estate, it was generally found to over predict productivity except where high standards of silvicultural practices such as fertiliser, weed and insect control had been applied. This result pointed to the benefits of implementing intensive silvicultural practices and helps explain the higher productivities found to be occurring in the new (post 1994) estate (West 1999a, 1999c).