SE 1.5

COMMERCIAL PLANTATION LAND CAPABILITY ANALYSIS OF SOUTH EAST QUEENSLAND

QUEENSLAND CRA/RFA STEERING COMMITTEE

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FINAL REPORT

OCTOBER 1998

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This project has been jointly funded by the Queensland and Commonwealth Governments. The work undertaken within this project has been managed by the joint Queensland / Commonwealth CRA RFA Steering Committee and overseen by the Socio–Economic Technical Committee.

ACKNOWLEDGEMENTS

The CRA unit would like to thank the individuals who provided valuable input to this report through their participation in the workshop which was held to gather information regarding the soils and plantation capability of South East Queensland.

Particular thanks to Paul Ryan of QFRI for his assistance in developing decision matrices, attributing maps and for reviewing this report.

Thanks are also due to the individuals who took the time to review draft versions of this report and provided valuable comments.

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SUMMARY

This report has been prepared for the joint Commonwealth/State Steering Committee, which oversees the Comprehensive Regional Assessment (CRA) of forests in the South East Queensland RFA region.

The Comprehensive Regional Assessment provides the scientific basis on which the State and Commonwealth governments will sign a Regional Forest Agreement (RFA) for the forests of the South East Queensland CRA region. This agreement will determine the future of the region's forests and will define those areas needed to form a comprehensive, adequate and representative (CAR) reserve system and those available for ecologically sustainable commercial use.

This report was undertaken to investigate at a broad level, the capability of land in SEQ for the development of native and exotic plantations to supply a range of wood products. It is part of a more comprehensive research and development program investigating plantation potential. The plantation capability analysis considered both public and private land.

Five plantation types were evaluated in this study. These were:

- Hoop Pine (a native softwood)
- Exotic Pine (specifically the F1 hybrid of Caribbean and Slash Pines)
- Spotted Gum
- Queensland Western White Gum
- a group of three native hardwoods (comprised of Blackbutt, Gympie Messmate and Rose Gum).

These species/groups include those species considered to be most promising and that cover the range of soil and climatic conditions that occur in SEQ.

Of the 3.4 million ha of cleared land in SEQ, the project identified approximately 2.7 million hectares larger than 10 ha, with cleared areas greater than 10 ha, and slopes of less than 25 degrees. Two hundred thousand hectares of this land is currently used for cropping or improved pasture and thus considered to be high value, the remaining 2.5 million ha was considered to be (relatively) low value cleared land.

Plantation capability was determined using an expert model. This involved identifying key variables affecting plantation capability and establishing constraints on these variables. Soil characteristics and rainfall were identified as being the main variables. Due to comprehensive coverage of soils being unavailable, 1:500 000 geology or land resource area maps were attributed with soil characteristics. A plantation soil suitability score was defined for each of the land units for each plantation type. A matrix was then developed between this and rainfall to establish plantation capability for each plantation type.

The analysis resulted in reasonable results for the exotic softwood, Spotted Gum, and the group of three eucalypts, although a large area is predicted to be of high or medium capability for Spotted Gum. There is less confidence over the Hoop Pine prediction and no validation of Queensland Western White Gum. There is also considerable variability within the classes thus only a proportion of the area identified in any class would actually reach the predicted potential.

If only the areas that were identified as being high or medium capability are considered, then the following areas for each plantation type were identified as capable:

Species (group)	Area of high plus medium capability land (ha)	
	Low value land	High value land
Exotic softwood	589 000	76 000
Native softwood	567 000	64 000
Qld Western White Gum	1 247 000	128 000
Spotted gum	1 789 000	174 000
Blackbutt, Gympie Messmate, Rose Gum	595 000	67 000
All hardwoods	2 105 000	194 000

It should be noted that these are areas that are considered capable of plantation establishment, rather than those that are available or economically feasible. The areas available for plantation establishment would be lower as a result of distance from markets, competing land uses and land value excluding potentially capable areas on economic grounds.

Due to the scale at which the data for this project was gathered, the results of this report provide a broad general picture of the plantation capabilities of South East Queensland. Additional studies being conducted jointly by DNR and QFRI include spatial regression modelling of native species to better define areas of plantation capability. Preliminary results from this work will be available as inputs to the RFA option development process.

1. INTRODUCTION

1.1 BACKGROUND

Plantations already supply a large proportion of wood requirements for South East Queensland (SEQ). The majority of plantation development to date in SEQ has either been with native or exotic softwoods, which provides little opportunity for supplying resource for hardwood based operations and markets currently relying on the native forest resource. The capability of land in SEQ for the development of plantations to supplement the existing native forest and plantation resource, needs to be evaluated and reported as part of both the RFA process and other plantation initiatives.

Terminology adopted in this report in relation to plantations is as follows. Land **capability** assessment identifies locations where the biological requirements of a species are satisfied. Land **suitability** then considers both the land capability and socioeconomic factors to determine the economic viability and social acceptability of using land for plantations. Land **availability** refers to the willingness of landowners to make their land available for plantation establishment.

Consideration of plantation development for Queensland needs to be viewed in light of both the RFA and other plantation initiatives being undertaken by government. The Queensland Forestry Research Institute (QFRI) has developed a comprehensive strategy for hardwood plantation research and development (Keenan *et al* 1998). This strategy involves a series of research programs, one being the ‘Land Availability Program’.

The Land Availability Program involves the broad assessment of land capability and more detailed matching of species to sites using spatial regression analysis and estimating potential productivity using both spatial regression analysis and physiological models. This project provides the broad assessment of land capability for use at a policy and broad planning level.

The more detailed site matching using spatial regression modeling is currently being undertaken by DNR using DPI–F temporary plot data. Initial models have been developed for a number of species detailing potential sites with preliminary analysis of productivity. These will be further refined, with outputs available for RFA option development. Additional components of the proposed R&D strategy include trials located strategically to cover a range of climatic and edaphic conditions. Data generated by these trials will enhance the information available for refining species/site matching and productivity models.

Thus the analysis presented in this report should be viewed in light of the broader initiatives being undertaken in the area of plantation suitability. This work provides a base data set for the broad level identification of sites capable of plantation establishment, required for identifying timber industry development options during the option development stage of the RFA.

1.2 OBJECTIVES

To investigate the capability of land in SEQ for development of native and exotic plantations to supply a range of wood products.

This project addresses the following issues:

- priority native hardwood and softwood and exotic softwood species suitable for commercial plantations are identified
- cleared public and private land is identified
- productive potential for plantations on cleared land is predicted.

1.3 PROJECT SPECIFICATIONS

A copy of the project specifications appears in Appendix A.

2. METHODS

2.1 OVERVIEW

The method included the following components:

1. A range of target native and exotic species and species groups was identified following consideration of growth characteristics, potential products/ uses and commercial viability.
2. Land Resource Area maps for the northern half of the bioregion and the Moreton geology sheet for the southern half were attributed with dominant soil characteristics and for plantation soil suitability.
3. Key environmental variables were identified by experts and from literature that limit site suitability of the selected species.
4. Land capability was analysed spatially according to limiting environmental characteristics of the targeted species.
5. The resultant spatial analysis of land capability was then evaluated against existing plantations (for softwood species) and presence data (for native species within the region). They were also subject to expert review.
6. Key operational constraints such as cleared land, slope and lot size were taken into consideration.
7. The resultant spatial analysis of land capability was interpreted with respect to potential for plantation establishment.

2.2 SPECIES SELECTION

A range of native hardwood and softwood species, and exotic softwood species is considered suitable for plantation establishment in SEQ. Commercial viability of species for plantation establishment will depend on inherent characteristics such as wood quality, growth potential and environmental requirements, and also other issues such as market potential, suitability for a range of sites, relative freedom from known pests and diseases and existing knowledge of these characteristics for each species.

Experts in plantation research and development from the Queensland Forestry Research Institute (QFRI) identified 57 potentially suitable species (apart from native and exotic pines), that were rated on a scale of 1 to 3 in terms of the viability characteristics noted above. These comprised 43, 33 and 14 species suitable for subtropical, warm temperate and dry forest situations respectively. Some species overlapped the climate zones. The list was reduced to a manageable size of five species/species groups by identifying those species that showed most promise and that cover the range of conditions found in South East Queensland.

Identification of native and exotic pines was based on those species/crosses that have proven to be successful in existing plantation situations.

2.3 SOIL ATTRIBUTING

Soil type and its characteristics have a major influence on the suitability of a site for plantation establishment. Detailed soil mapping is generally confined to intensive agricultural areas and rarely those areas that would be available for plantation establishment. Comprehensive soil coverages are required for detailed spatial analysis of land capability for particular species. The absence of such coverage was a major limiting variable.

To enable soil properties to be included in the analysis of plantation capability, land units across the SEQ region were attributed with values for several soil properties. Land units in the south of the region were identified by grouping the 149 geology units on the Moreton geology map into 13 broad stratigraphic units. In the north of the region the land units were identified from the Port Curtis–Wide Bay and Inland Burnett Land Resource Area (LRA) maps. The LRA units shown on these maps were based to a large extent on the underlying geology. All of the maps used in this process were at a scale of 1:500 000. There is a small area in the north of the RFA region that is not covered by the LRA maps and this area was excluded from the analysis as a consequence. The area of the Blackdown Tablelands within the SEQ biogeographic region was also excluded from the study as this is predominantly timbered State forests and national park.

For each of the land units on these maps, values were assigned for each of the four soil properties of interest on a relative 1–10 linear scale. The soil properties and the factors that were considered included:

Fertility (Nutrient Supply Potential):
- chemistry and degree of weathering of both the regolith and the solum
- mineralogy of the regolith
- soil organic matter development
- texture of the soil
- soil genesis factors such as depth of B horizon

The higher the score, the more fertile the soils likely to be found in that land unit.

Permeability (Drainage):
- degree of fracturing of the regolith
- texture and porosity of the soil
- soil genesis factors such as depth of B horizon

The higher the score the more permeable the soils likely to be found in that land unit.

Depth of Soil:
- depth of solum above the regolith
- degree of weathering of the regolith
- the position of perched and permanent water tables
- degree of fracturing of the regolith

The higher the score the deeper the soil likely to be found in that land unit.

Texture (Soil Water Holding Capacity):
- impact of soil texture on water holding capacity.

Coarse soils with low water holding capacity will have a low score, whereas fine textured soils with a high water holding capacity will have a high score.

Two workshops were held to provide a forum for a panel of specialists to discuss the values to be attributed to each land unit for each soil property. Experts in the fields of soil science and geology determined the values to be attributed to each of the soil properties for the various land units. The first workshop was held in 1992 when the DPI–F convened a panel of experts to assign attributes to the 13 broad stratigraphic units derived from the Moreton geology map. This work was undertaken to assist with species modelling being undertaken at the time and was directly relevant to this project. The panel included:

Bernie Powell	Department of Primary Industries
Bill McDonald	Queensland Herbarium
Len Cranfield	Department of Mines and Energy
Erol Stock	Griffith University
Peter Young	Department of Environment

A second workshop was held in 1998 using the same procedure to assign soil and plantation attributes to the two Land Resource Area maps which cover the north of the bioregion. The CRA unit convened this workshop. The expert panel included:

Justin Claridge	Department of Natural Resources – Land and Environment Assessment
Len Cranfield	Department of Mines and Energy
Ben Harms	Department of Natural Resources – Land and Environment Assessment
Bernie Powell	Department of Natural Resources – Land and Environment Assessment
Paul Ryan	Queensland Forest Research Institute
John Simpson	Queensland Forest Research Institute
David Taylor	Queensland Forest Research Institute
Peter Young	Department of Environment

Many of the land units were attributed with a range for the soil properties. The ranges given to the land units fell into two classes. There were those that have quite narrow ranges and those that were quite broad. The narrow classes tended to result from ranges in the properties of effectively the same soils preventing the panel from settling on a single value for the unit. The relict alluvial plains were attributed with quite narrow ranges for each of the soil properties, indicating some differences within the unit but the soils in the unit are basically homogenous. The units with broad ranges attributed to them generally contain quite different soils. An example of this would be the flood-plains that have quite different soils in areas close to the coast compared with those further inland.

2.4 PLANTATION SOIL SUITABILITY

Following the attribution of soil properties to the land units on the geology and LRA maps, those with expertise in the areas of plant ecology and plantation silviculture used this information to assign a value for plantation soil suitability to each of the land units. These values were determined considering only the soil properties under adequate natural rainfall. Plantation soil suitability of the land units was rated as High, Medium, Low or Unsuitable based on the maximum potential productivity[1] of the soil types for each plantation type. Table 2.1 presents the productivity classes.

[1] Potential productivity was taken to be total maximum volume production within the environmental parameters of the analysis and exclusion of factors such as merchantability criteria, other biological limitations (such as loss of growth due to insect herbivory and weed competition) or the effects of silvicultural manipulation to increase stand value (such as thinning).

Table 2.1 Description of Plantation Productivity Classes

High:	> 20 m^3/ha/yr MAI
Medium:	15–20 m^3/ha/yr MAI
Low:	10–15 m^3/ha/yr MAI
Unsuitable:	< 10 m^3/ha/yr MAI

The panel members generally based their decisions on the soil properties of permeability, depth and texture. Fertility was also considered, but to a lesser extent as this property can be manipulated by including fertiliser application in the plantation silviculture.

As for the soil properties, many of the land units were also attributed with a range of plantation soil suitabilities, based on the range of soil properties within the land unit. The expert panel jointly attributed the two northern LRA maps whereas Paul Ryan of QFRI attributed the Moreton geology sheet.

2.5 PLANTATION CAPABILITY

In defining plantation capability, rainfall was considered to be the critically limiting environmental factor in combination with soil suitability. As such these were the only two features used in establishing plantation capability. Rainfall requirements of each of the plantation types were determined by consulting with the plantation specialists on the expert panel. Plantation capability classes were then developed for each species by identifying classes of annual rainfall limits and matching these with the soil suitability classes.

Sets of decision matrices were developed, detailing soil suitability, rainfall and plantation capability for each of the plantation groups. These were then analysed spatially using a GIS, resulting in a series of spatial coverages detailing predicted plantation capability.

2.6 VALIDATION OF MODELS

The plantation experts involved in the initial attribution perused maps of the projected suitabilities to check for anomalies. The results of the assessment were further validated by intersecting the projected capability (by class) with known site information. For the pines, this was done using a plantation coverage that detailed existing native and exotic plantations. Readily available site information from DPI–F temporary plots was used to validate the hardwood projections. Due to its natural distribution being outside of the region, no data was available for Queensland Western White Gum (*E. argophloia)* to enable verification. These were evaluated by perusing the mapped output and interpreting a tabular analysis.

2.7 AVAILABLE LAND

In identifying land available for plantation establishment, a number of operational constraints were considered. The key features considered were:

- cleared land
- slope
- lot size and cleared area
- current land use.

Cleared land was derived from the Murray–Darling Basin Project M305 (Ritman 1995) which used LANDSAT scenes from 1989 – 1991 to classify the study area according to a range of features including vegetation density and land cover types. This was the only comprehensive coverage available at the time. The maximum vegetation density of 20 per cent crown cover was used to define cleared land. This was the limit used in the Murray–Darling Project to define woody/non-woody vegetation.

A slope limit of 25 degrees was used as the limit of capable land. This is the limit as defined by the Draft Code of Practice for Plantations (DNR 1998) as being suitable for plantation establishment without special management prescriptions and suitable harvesting techniques to minimise erosion and adverse off-site impacts. However, suitability even to 25 degrees is recognised as being dependent on erodability of sites. DPI–F uses a general limit of 20 degrees for plantation joint venture proposals (DPI–F undated).

Property and cleared area size limits were established to define those areas that would viably contribute to the plantation estate. A nominal limit of 10 ha was used to screen property sizes and cleared areas. This was based on the minimum size used by DPI–F in their plantation joint ventures (DPI–F undated). Property size was derived from the Digital Cadastral Database maintained by DNR and cleared area derived from the Murray Darling Basin vegetation density classification.

Land value is clearly a critical variable that influences the viability of land for plantation establishment. Although somewhat beyond the scope of the project, results are differentiated according to current land use. The Murray–Darling Basin land cover type distinguished areas of cropping and pasture from grasslands. Areas of cropping and pasture are considered to be high value land uses and less likely to compete with plantation as a land use. As such, these classes of cleared land have been reported separately.

Urban areas were also defined by the Murray–Darling Basin land use mapping. Although generally captured by the screen for lot size, urban areas were excluded from the analysis.

2.8 LIMITATIONS OF METHODS

The analysis method used in this study was based predominantly on expert knowledge. This was a result of the time and resources available to this project and the expertise available, however at the time of the project proposal it was considered to be the most appropriate method. Ongoing work within DNR is using more detailed spatial regression analysis to establish site requirements of many of the species selected for this study. This is resulting in models based on empirical data rather than expert knowledge.

The range of species considered in this analysis was limited to only five groups. Clearly there are far more species that could potentially be used for plantation purposes in South East Queensland. This is highlighted by the original list containing 57 potentially useful species. The simplification was considered necessary to arrive at a workable number of species (groups) and the results from many of the species (groups) are thought to be applicable to a number of other species.

The underlying geology and land system maps used to attribute with soil properties were collated at 1:500 000 scale. The 149 geological types from the Morton Geology sheet were grouped into 13 classes to facilitate attribution. The scale and collation resulted in considerable variability of soil types within the land units. Clearly some of the land units were more heterogeneous than others, and these were attributed with a range of values for some properties in addition to the predominant value. The ranges were carried through into plantation soil suitability, resulting in variability within capability classes.

Further work is being proposed, outside of the RFA process, to attribute geology base maps with soil properties at 1:100 000 scale, which will address many of the issues raised above. The attribution method will be modified from the expert model used in this study. Data that establishes a relationship between soil depth and productivity of individual species are required as it seems likely that in many cases 'soil depth' as defined in soils surveys does not necessarily correspond with the depth of soil accessible to tree roots. If a more accurate prediction of the plantation capability of the region is to be obtained, these knowledge gaps need to be filled.

There are some minor issues related to use of the 1989–91 LANDSAT scenes as a basis for determining currently cleared areas and current land use. Work has been done on more recent (1997) LANDSAT scenes covering the study area, but these are not yet in a useful form. The more recent images would obviously provide a more contemporary view of cleared area/land use.

The project specification required the consideration of predicted climate change in the method. During the course of the project it became obvious that the requirement of this part of the method was beyond the capacity of the project to deliver a viable outcome.

The areas identified and capability classes are indicative only and may be under or overestimated due to the range of soil attributes (and hence productivity potential) within each land unit. Since most of the land units have a range of capability classes, only a proportion of the areas classified as being high, medium, low or unsuitable would have that actual capability value.

3. RESULTS

3.1 SPECIES SELECTION

Table 3.1 lists the priority species identified by key plantation experts from the Queensland Forestry Research Institute (QFRI). A description of actual and potential plantation species, their growth habits and products/uses is provided in Appendix B – Description of the Species to be Considered, which was prepared by the Bureau of Resource Sciences.

Table 3.1 Priority Species List

	Priority 1	Priority 2
Hardwoods	Gympie Messmate Blackbutt	Rose Gum (included in group with Gympie Messmate and Blackbutt) Red Mahogany Tallowwood Dunn's White Gum
	Queensland Western White Gum	Forest Red Gum
	Spotted Gum	Large Leaved Spotted Gum White Mahogany
Softwoods	Hoop Pine	
	F1 hybrid (*Pinus elliottii x P. caribaea*)	F2 hybrid (*P. elliottii x P. caribaea*) Caribbean Pine Slash Pine

Five plantation types were identified from the list in Table 3.1, made up predominantly from priority 1 species. These being the Hoop Pine (*A. cunninghamii),* the exotic softwood (F1 hybrid *P. elliotti x P. caribaea*) and the native hardwoods which were divided into three categories: Queensland Western White Gum *(E. argophloia*), Spotted Gum *(C. citriodora*), and a group containing Blackbutt *(E. pilularis),* Gympie Messmate *(E. cloeziana)* and Rose Gum *(E. grandis).*

These species were selected as they best met the selection criteria such as wood quality, growth potential and environmental requirements as outlined in section 2.2. These species were also chosen because they have quite different site requirements from each other. This ensured that the maximum range of potential sites had been analysed. In addition, the maximum range of species per site interactions had been considered.

The results of this analysis can also provide information regarding the plantation capability of the priority 2 species. Each of the priority 2 species share similar environmental requirements with those species included in the priority 1 list (see Table 3.1). For example Forest Red Gum (*E. tereticornis*) has similar requirements to Queensland Western White Gum though plantation potential may be extended into higher rainfall areas. White Mahogany (*E. acmenoides*) and Large Leaved Spotted Gum (*C. henryi*) have similar environmental requirements to Spotted Gum. Red Mahogany (*E. resinifera),* Tallowwood (*E. microcorys)* and Dunn's White Gum (*E. dunnii)* have similar requirements to the group of three eucalypts though they would tend towards the moister and more fertile, and Dunn's White Gum, cooler end of the spectrum. The F2 hybrid *P. elliottii x P. caribaea*, Caribbean Pine (*P. caribaea)* and Slash Pine (*P. elliottii)* have similar environmental requirements to the F1 hybrid *P. elliottii x P. caribaea*.

3.2 SOIL ATTRIBUTING

A table detailing the fertility, permeability, depth and texture values attributed to each of the land units by the panel for each of the maps is presented in Appendix C. Note that most of the soils were attributed with ranges for various properties.

3.3 PLANTATION SOIL SUITABILITY

Tables detailing the plantation soil suitability scores for each of the plantation types and land units are shown in Appendix D. As a result of the ranges in soil properties, it can be seen that many land units have ranges associated with the plantation soil suitability score. The Moreton geology sheet in particular has ranges associated with most of the units. In all cases, a value has been given which represents the most likely plantation suitability to be found in that unit.

3.4 PLANTATION CAPABILITY

Plantation capability matrices combining the soil suitability scores and rainfall values are presented in Appendix E. These are based on the predominant plantation soil suitability score.

3.5 VALIDATION OF MODELS

Table 3.2 provides the details of the predicted plantation capability for the total region, and the intersection with both existing plantations and/or site presence data for modelled species apart from Queensland Western White Gum.

Table 3.2 Percentage of total region by predicted capability class and intersection with existing plantations or available site data.

Species	High	Medium	Low	Unsuitable	Total area / No. of sites
Pinus*					
% predicted	1	34	33	32	5,888,084 (ha)
Existing plantation	6	84	3	7	148,144 (ha)
Hoop Pine					
% predicted	3	23	27	47	5,888,084 (ha)
Existing plantation	8	41	18	33	44,656 (ha)
Observed presence	9	33	19	39	224 (sites)
Spotted Gum					
% predicted	18	55	24	4	5,888,084 (ha)
Observed presence	12	73	14	0	5,186 (sites)
Blackbutt					
% predicted	24	4	29	43	5,888,084 (ha)
Observed presence	21	32	38	8	1,877 (sites)
Gympie Messmate					
% predicted	24	4	29	43	5,888,084 (ha)
Observed presence	45	31	8	16	180 (sites)
Rose Gum					
% predicted	24	4	29	43	5,888,084 (ha)
Observed presence	35	31	28	6	1,300 (sites)

* includes State and private plantations.

All of the plantation groups apart from Hoop Pine have a reasonable match between existing plantation or site data and the overall projected areas of capability. The distribution of the existing plantations and site data within capability classes for some species has a higher proportion within the Low capability class rather than in the High capability class as would be expected. There are a number of possible explanations for this:

- plantations are generally planted on suitable land that is available within financial and other constraints, rather than the most productive land
- the natural distribution of species does not necessarily reflect the most productive sites for that species due to the range of ecological factors, including competitive ability, that influence species distribution
- there is significant variability within any predicted capability class
- the model may not be accurately differentiating between capability classes.

Paul Ryan[2] (pers. comm.) suggests that all of these points are likely to apply to a greater or lesser degree depending on the species.

The range within capability classes is highlighted by two examples from the Hoop Pine prediction. Predicted capability for hoop pine plantation over Benarkin State Forest (which contains a high proportion of productive hoop pine plantation) is rated predominantly as unsuitable or having low capability while only a small proportion is rated as being of medium capability. On the other hand there is an extensive area around Gympie that is rated as being of medium capability for hoop pine though actual ratings would range from unsuitable to highly suitable. In both cases, the scale of the land unit mapping masks finer resolution of capability classification.

Further analysis was undertaken of the Hoop Pine predictions to evaluate this variability, and in particular why such a large proportion of existing plantation falls on sites classified as unsuitable. The major areas of hoop pine plantation on land modelled to be unsuitable were found to be on soil suitability classes that were heterogeneous; i.e. most were classified as low or unsuitable with occasional medium or occasional low. Recalculation of the areas considering the occasional plantation soil suitability classes are presented in Table 3.3

Table 3.3 Intersection of predicted plantation capability (including 'Occasional' classes) for Hoop Pine with existing plantations.

	High	Medium	L Occ M	Low	U Occ M	U Occ L	Unsuitable	Area (ha)
Hoop Pine	8%	40%	5%	13%	2%	26%	6%	44,496

While this analysis indicates that fewer areas are located solely in the unsuitable class, it does highlight a number of issues. In particular:

- There is considerable heterogeneity in underlying mapping units due to their scale, and as such these are indicative only.
- The model is predicting, at maximum, only low capability for 39 per cent of the existing plantation estate. This appears to be related to the rainfall interaction with the plantation soil suitability score, as most of the underlying plantation soil suitability is classed as medium or occasional medium.

[2] Paul Ryan – Principal Scientist, Queensland Forest Research Institute

The prediction for Queensland Western White Gum could not be validated using any site data as this species does not occur naturally within the study area and existing data are too limited to enable comprehensive validation. As such, comments are limited to general observations. Preliminary results indicate a relatively high proportion of land classified as ‘capable’ for this species. The species has quite different soil requirements to the other species since it grows well on soils of heavy texture with relatively slow drainage. The species appears to have a broad distribution of potentially capable sites. However, it is likely that the species would reach its estimated potential on only a proportion of the sites modelled as capable.

3.6 AVAILABLE LAND

Table 3.4 details the area of cleared land by value, both with and without suitability constraints.

Table 3.4 Areas of cleared land by value (derived from Murray–Darling Basin analysis)

	Low value (ha)	High value (ha)	Total area (ha)
Cleared area – constrained*	2,486,314	236,576	2,722,890
Total cleared area	3,146,768	276,919	3,423,687

Area constrained to: lot size > 10 ha, cleared area > 10 ha and slope < 25 degees.

3.7 SPATIAL ANALYSIS

Maps 1–5 show the areas of predicted capability for each plantation type, taking into account the operational constraints of cleared land, lot size, slope and current land use. Table 3.5 summarises the areas of capability for each plantation type.

Table 3.5 Areas of plantation capability in SEQ for each plantation type by 2 classes of land value.

Plantation Type	Area in Each Capability Class (ha)			
	High	Medium	Low	Unsuitable
Exotic softwoods				
Low value cleared land	*13,856*	*575,377*	*956,415*	*940,666*
High value cleared land	*873*	*74,707*	*72,141*	*88,855*
Total	14,729	650,084	1,028,556	1,029,521
Native softwoods				
Low value cleared land	*43,475*	*523,737*	*726,540*	*1,192,562*
High value cleared land	*5,268*	*58,253*	*50,370*	*122,685*
Total	48,743	581,990	776,910	1,315,247
E. argophloia				
Low value cleared land	*422,212*	*824,528*	*669,210*	*570,364*
High value cleared land	*42,522*	*85,067*	*38,691*	*70,296*
Total	464,734	909,595	707,901	640,660
C. citriodora				
Low value cleared land	*294,888*	*1,494,456*	*627,785*	*69,185*
High value cleared land	*26,173*	*147,393*	*54,117*	*8,893*
Total	321,061	1,641,849	681,902	78,078
E. pilularis, E grandis & E. cloeziana				
Low value cleared land	*535,201*	*59,910*	*750,701*	*1,140,502*
High value cleared land	*47,588*	*18,914*	*50,838*	*119,236*
Total	582,789	78,824	801,539	1,259,738
All hardwoods (highest potential)				
Low value cleared land	*871,427*	*1,233,155*	*329,535*	*52,197*
High value cleared land	*85,688*	*108,194*	*35,844*	*6,850*
Total	957,115	1,341,349	365,379	59,047

Cleared land is differentiated into high value (areas currently used for pasture or cropping) and low value (other cleared areas).

4. DISCUSSION

Of the 2.72 million ha of cleared land meeting slope and size constraints, 237 000 ha is high value agricultural land and the remainder considered in general to be of lower value. Capable land was identified for all plantation types within the potentially available land.

In interpreting the results of this study it is important to recognise the limitations of the study method, as outlined in section 2.8 and the results of the validation procedure, as outlined in section 3.5. In particular, the areas identified as being 'capable' of supporting plantation in fact indicate the general area in which land of that capability class is most likely to be found. The capability classes are indicative of the general productivity expected within each area, however there is clearly variation within these classes.

Validation for the exotic pine indicated a relatively sound model. Although there was only a small area of high productivity land identified, a high proportion (84 per cent) of existing plantations fell over areas predicted to be of moderate capability. Sixty five percent of the region was predicted to be of low or unsuitable and only 10 per cent of existing plantations fell over these classes. A total of 665 000 ha of high and medium capability land was identified.

The prediction for Hoop Pine appears to be less reliable than those for the other species. Although the validation indicated that the predictions covering current plantation areas may indicate capability if the 'occasional' classes are used, these are still indicating that a high proportion of existing plantations are in the low capability class. Given this, it is recommended that further work be undertaken to improve the reliability of Hoop Pine predictions, possibly using an alternative modelling method.

The lack of experience with the species, lack of validation and relatively large area (2.1 M ha) modelled as capable for Queensland Western White Gum would suggest that the projection for this species be used with caution. This species was selected due to its site requirements being different from other hardwood species. As such it is an important component of the suite of species evaluated. However, further work is required on this species and this may be limited to more detailed knowledge based models.

For the hardwoods, the greatest area of capable land was identified for Spotted Gum. This is consistent with its broad distribution across the region. The validation indicated that 85 per cent of the plot data fell within the 73 per cent of the region predicted to be of high or medium capability land. A total of almost 2 million ha of land was predicted to be of moderate to high capability. Although the species has a broad distribution, this would appear to be an optimistic prediction of capability.

Validation of the group of three eucalypts, Blackbutt, Gympie Messmate and Rose Gum, indicates that the natural distribution of these species falls predominantly within the 57 per cent of the region predicted to be capable for these species. The distribution of land between capability classes has only a small proportion within the medium class. The relatively large proportion of high would indicate that some of these sites are more likely to be of medium capability.

When combined, almost the whole region is predicted to be capable of supporting hardwood plantations, with 84 per cent predicted to be in the high or medium capability classes. Clearly this is an overestimate of the potentially capable land. The extent of the Spotted Gum and Western White Gum predictions are the main factors influencing this result.

The land use classes used for the analysis are very simple surrogates of land value. Whilst it is less likely that plantations will be a viable alternative to cropping or pasture on the 240,000 ha of this land, this assumption has not been tested. However, there are a number of other factors that will influence feasibility beyond those considered in this study. These include:

- Tenure – ownership of capable land will influence availability for plantation establishment.

- Location of markets – the location of markets and potential markets would need to be identified and taken into consideration when identifying areas for plantation establishment. The cost involved in transporting timber from plantation areas to processing sites and markets will heavily influence the viability of plantations.

- Size of individual and aggregate units – economic viability of plantations requires a minimum area as a management unit (at both individual property lot level – which has been considered – and at an aggregate level) and as a marketing unit (at an aggregate level).

- Land price – the cost of land will influence the economic viability of establishing a plantation and hence whether or not it is available for conversion to plantation. Whilst this has been addressed to some extent in the study, viability is highly dependent on actual land price and potential plantation productivity.

- Consideration of any local government zoning for forestry activities.

The study highlighted the problem of the inadequacy of soils information in relation to potential plantation productivity. The major limiting factor in this project was the lack of accurate soils information for the bioregion. Detailed soil mapping has been completed for areas of agricultural importance but no such information exists at a broader level or for land that would be potentially available for plantation establishment.

However, regardless of the scale of the data and the inherent problems with investigating at this scale, for most species (groups) the results of this project provide an indication of the areas with potential for plantations in SEQ and that warrant further investigation. This project provides broad information that will be used as a starting point for other projects to examine areas of capability in more detail. Other work being undertaken in relation to plantation capability modelling will over time provide more precise indications of plantation capability. These will permit far more detailed evaluation of the potential productivity and hence permit more detailed feasibility analysis.

5. RECOMMENDATIONS FOR FURTHER WORK

Further work in the area of plantation capability should focus on the precision of any estimates. It is recommended that for native species this focus on spatial regression modelling using site data for natural populations of the species in question. Current modelling in this area should deliver preliminary results to assist with RFA option development. Limitations of species site data and soils data should be addressed where possible for this work.

Collation of site data requires a cooperative effort between all Queensland agencies to pool data. This would not only permit more accurate prediction of plantation capability, but also assist in understanding ecological features driving species distribution.

Establishing an accurate picture of soils across the region is also considered critical to improving predictions. A project is currently being established within DNR to better address this need by establishing a more robust and repeatable method for quickly attributing geology maps at 1:100 000 scale. While this will not be available for the preliminary work, it is anticipated that this will significantly improve the prediction of plantation capability over time.

The prediction for Hoop Pine developed in this report appears to be unreliable. Further work is required in establishing a more robust model for this species. Differentiation of the pre-European vegetation mapping according to productivity may provide some opportunity for addressing this need.

In addition, it is recommended that the prediction for Queensland Western White Gum be used with caution.

Considerable work is still required to enable detailed planning for a major plantation establishment program. Field verification of any prediction is required prior to detailed planning of actual plantings. This should be based on the most accurate modelling available and should also consider viability. Consideration of economic feasibility and social impacts of major plantation development are also required prior to large scale plantation establishment.

Clearly all this work requires coordination with current plantation developments such as the *Hardwood Plantation R&D Strategy* (Keenan *et al* 1998) and existing government initiatives such as the *Plantations for Australia: The 2020 Vision* (MCFFA *et al* 1997) that has been adopted by both the State and Commonwealth governments.

6. CONCLUSIONS

This study evaluated the capability of the 3.42 million ha of cleared land in the SEQ RFA region to support plantations. It identified five plantation species/species groups for analysis. These are: exotic softwoods, Hoop Pine and three hardwood species/species groups. The species selected aim to cover both the existing preferred softwood species and a range of desirable hardwood species that provide broad coverage of the range of soil and climatic conditions found in SEQ.

Of the 2.72 million ha of land meeting the operational constraints, the study indicated that 24 per cent of this was of high to medium capability for the exotic pine. From Table 3.5, 50 per cent, 72 per cent and 24 per cent of this land was predicted to be of high or medium capability for Western White Gum, Spotted Gum and the group of three eucalypts respectively. When combined, 84 per cent of the region was predicted to be of high or medium capability for at least one of the hardwood species/species groups. This appears to be an overestimate of the proportion of the region that would be capable of achieving medium to high plantation growth rates.

These results must be interpreted with caution. In particular, the Hoop Pine model does not provide a high level of certainty. It is recommended that further work be undertaken for this species. In addition, results for Queensland Western White Gum should also be interpreted with caution, as a large area is predicted as being capable for the species. Whilst this may turn out to be a broad ranging species, the species does not naturally occur in the region and is relatively untested in plantation situations. The area of higher capability for Spotted Gum also appears to be large.

This study provides indicative locations of land capable of supporting plantations for most of the species (groups) evaluated. Whilst considerable caution is required in interpretation of the results, they provide a general spatial indication of the land within the South East Queensland region capable of plantation establishment.

It is recommended that further work be undertaken on improving the precision of the predicted capability. In particular, the use of spatial regression modelling with improved base soil and vegetation site data sets should achieve this for most of the identified species. Preliminary results should be available to assist with RFA option development. Any further work must be coordinated with existing plantation R&D programs and plantation development initiatives.

APPENDICES

APPENDIX A Project Specifications

PROJECT NAME:	**Commercial plantation land capability analysis**
PROJECT IDENTIFIER:	**SE 1.5**
LOCATION/EXTENT:	**SEQ biogeographic region**
ORGANISATION/S:	**DNR** **DPI–Forestry** **BRS**
CONTACT OFFICERS:	**Jim Burgess (Forest Planner), Doug Ward (Resource Analyst)** **Malcolm Taylor (Senior Planning Officer)** **Dan Sun (Senior Research Scientist)**

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LINKAGES/DEPENDENCIES: Successors:

PI 2 Integration of socio-economic layers (limited linkages, SE 1.5 provides a base data set)

PI 6 Timber industry development options (SE 1.5 provides base data set)

TYPE OF STUDY: **Resource**

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1. OBJECTIVES OF THE PROJECT

- To investigate the capability of land in SEQ for development of native and exotic plantations to supply a range of wood products.
- Project addresses clause 4 of the Scoping Agreement

2. BACKGROUND

Plantations already supply a large proportion of wood requirements for SEQ. The majority of plantation development to date in SEQ has been either native or exotic softwoods, which provide little opportunity for supplying resource for hardwood-based operations and markets currently relying on the native forest resource. The capability of land in SEQ for the development of plantations to supplement the available native forest and plantation resource needs to be evaluated and reported. This will provide a base data set for the identification of timber industry development options.

3. SCOPE OF THE PROJECT

- The project will address the following issues:
  - both native hardwood and softwood and exotic softwood species and species groups suitable for commercial plantations
  - identification of cleared public and private land
  - identification of the productive potential of land

- Financial viability, market development and general plantation development opportunities will be dealt with in project PI 6 Wood Industry Development Options.

- Ground truthing of modelled capability is beyond the scope of this project.

4. METHODOLOGY

A range of native and exotic hardwood species are considered suitable for plantation establishment in SEQ. Commercial viability of species will depend on inherent characteristics such as wood quality, growth potential and environmental requirements; and market potential including potential uses and demand for species by current processors. These factors will be assessed in the selection of species for consideration and the environmental requirements of the selected species will be used to model the capability of land for plantations. However, this will not preclude applications of results more generally to alternative species.

A modelling approach will be taken to identify land capability. ANUCLIM will be used to model climate variables and will allow consideration of predicted climate change. However a major limiting environmental data set is that of soils. Detailed soil mapping is generally confined to intensive agricultural areas and rarely those that would be suitable for plantation establishment. Geology mapping, attributed with variables important to plant growth by a panel of experts, covers the south of the bioregion to Gympie and this process would be required for geology sheets covering the north of the Bioregion. Detailed environmental requirements of potential plantation species will generally be dependent on careful definition of soil requirements. The absence of comprehensive soils coverages for the SEQ bioregion is a limiting variable required for detailed modelling of land capability for particular species.

Methodology will include the following components:

- identify a range of target native and exotic species and species groups considering growth characteristics, potential products/ uses and commercial viability.
- identify key environmental variables from literature and experts that define the environmental domains of the selected species. (e.g. rainfall, soil type, solar radiation)

- identify key operational constraints such as slope, minimum cleared area, current use.
- attribute geology maps for northern mapsheets.
- model land capability according to environmental characteristics of the targeted species and key operational constraints.
- interpret modelled land capability with respect to potential for plantation establishment.

5. CRITICAL PATH

Outcomes/Outputs

Maps, analysis and written report indicating:
- the extent and quality of cleared public and privately owned land within the study area capable of supporting commercial native hardwood, native softwood and exotic softwood plantations for the purpose of social and economic analysis.
- assumptions, base data sets used for modelling purposes and methodology.
- limitations of the study methodology and data sets.

Reporting

Progress Reports will be submitted to the Socio-economic Technical Committee each month. At completion of the project, a final assessment report will be produced and submitted to the Steering Committee. DNR (CRA Unit) is responsible for compiling the final report.

8. PERFORMANCE INDICATORS

Performance indicators for the project are:

- project outcomes are useable in the identification of timber industry development options;
- project builds effectively on existing knowledge base;
- completion of the project in timely manner;

9. QUALITY CONTROL

To ensure a high quality output, the following measures will be applied:

- Close collaboration and review of outputs by technical experts from CRC Sustainable Production Forestry
- Periodic review of progress by Social and Economic Technical Committee and CRA Project Manager (Qld)

APPENDIX B Description of Species to be Considered

Compiled by Bureau of Resource Sciences

Hardwoods

Eucalyptus cloeziana F. Muell. (subgenus *Idiogenes*) (Gympie Messmate)

Growth Characteristics

Eucalyptus cloeziana is most productive in southern Queensland, particularly in the Gympie area, hence the name Gympie Messmate. The tree may reach 55 metres in height with a diameter at breast height of 2 metres. The tree generally has an excellent stem form. In less than preferred environments the species can vary from a crooked tree less than 10 metres to a larger tree 20–35 metres of variable form (Boland *et al*. 1992).

Distribution and Growth Conditions

Around the Gympie region *E. cloeziana* occurs in tall open-forest or woodlands. It is frequently the dominant species in the stand (Boland *et al*. 1992).

The altitudinal range is 75 – 950 metres (Hills and Brown 1978; Boland *et al*. 1992). The climate is warm sub-humid to humid with the mean maximum temperature of the hottest month ranges from 29 – 34°C and the mean minimum of the coldest month is around 5 – 18°C. The species can tolerate light frosts. The mean annual rainfall varies from 550 to 2300 mm (Boland *et al*. 1992).

The species grows best on the metasediments or loams of volcanic origin with a moderate depth. Otherwise, *E. cloeziana* occurs on shallow soils over coarse sandstone or on shallow to moderately deep coarse-textured soils derived from granite which are moist. The soils are well drained, acidic and of low to moderate fertility (Hills and Brown 1978; Boland *et al*. 1992).

Potential Products/Uses

The wood is yellow-brown, heavy, strong and very durable. It has limited use for general construction. The wood is best suited for heavy engineering construction, railway sleepers, mine timber, posts, poles and scantling. Its high density 1010 kg m^{-3} and colour make it unsuitable for paper pulp, although it could be used for chipboard production (Hills and Brown 1978; Boland *et al*. 1992).

Commercial Viability

E. cloeziana plantations are viable in southern Queensland on deep, well drained soils with a mean annual rainfall over 800 mm per year. Its sensitivity to damage in the nursery and establishment phases is a disadvantage but the species has an excellent form, rapid growth rate and the ability to withstand a long dry season (Hills and Brown 1978).

Research and Development on *E. cloeziana*

List of currently published studies

- Dickinson, G. R., Nikles, D. G., Leggate, W., Sun, D. and Robson, K. J. ([unknown]) *Variation of Eucalyptus cloeziana in coastal north Queensland plantings and implications for future improvement strategies*. Unpublished.

Eucalyptus pilularis Smith (Blackbutt)

Growth Characteristics

Eucalyptus pilularis is a tall to very tall tree occasionally attaining nearly 70 metres in height and exceeding 3 metres at breast height. The crown is characteristically dense (Boland *et al*. 1992).

Distribution and Growth Conditions

E. pilularis usually occurs in tall open-forest of high quality. Sometimes, it occurs on drier slopes adjacent to rainforest (Boland *et al*. 1992).

The altitudinal range is from near sea level to less than 600 metres in the hotter climates. The mean maximum temperature for the hottest month is in the range 24 – 32°C and the mean minimum of the coldest month around 5 – 10°C. A few frosts may occur each year at the higher altitudes away from the coast. Mean annual rainfall is about 900 – 1750 mm with a distinct summer maximum farther north (Boland *et al*. 1992).

This species is typically found on gentle slopes of hilly country between the sea and the coastal escarpment of the Great Dividing Range. It mainly occurs on siliceous parent materials, including sandy loams or loams. The soils are frequently of low nutrient status. The species will suffer on soils which are poorly aerated, or of restricted root or moisture penetrability and it will not survive on temporarily flooded sites (Hills and Brown 1978; Boland *et al*. 1992).

Potential Products/Uses

The wood is light yellow-brown, hard, strong, stiff and tough with moderate to good durability. The wood density is around 900 kg m^{-3}. *E. pilularis* is straight grained and readily worked (Hills and Brown 1978).

E. pilularis is a very important hardwood species in coastal New South Wales and south-eastern Queensland. It is regarded as a general purpose construction timber. The wood is also used for poles, sleepers, flooring, chipboard and suitable for paper pulp. Fast growing young trees are prone to end splitting which can cause problems in sawn timber (Hills and Brown 1978; Boland *et al*. 1992).

Commercial Viability

The prospects for *E. pilularis* plantations in south eastern Queensland are good providing the specific environmental requirements are considered. The potential plantation sites should be situated in warm temperate or subtropical areas, almost frost free, where the rainfall exceeds 1000 mm per year. The soils should be free draining. Seeds from high quality areas of natural forest may increase wood yield potential (Hills and Brown 1978).

Corymbia citriodora **(Hook.) K.D.Hill & L.A.S Johnson (Spotted Gum)**

Growth Characteristics

Corymbia citriodora grows to a tall tree on favourable sites, usually attaining 35 – 45 metres in height and 1 – 1.3 metres in diameter at breast height. On drier and poorer sites it may be 20 – 35 metres in height and 0.7 – 1.2 metres in diameter. The tree characteristically has a clean and usually long, straight bole (Boland *et al*. 1992).

Distribution and Growth Conditions

C. citriodora typically occurs in open-forest to tall open-forest formation, sometimes in fairly pure stands but also has many common associations. It is widely distributed in the coastal areas of New South Wales and southeast Queensland (Boland *et al*. 1992).

The altitudinal range is from near sea level, to about 950 metres for the northern regions of its distribution. The area is in the warm humid to warm sub-humid climatic zone. The mean maximum temperature of the hottest month is in the range 25 – 30°C and the mean minimum of the coldest month is around 1 – 8°C. Light frosts are tolerated by the species. The mean annual rainfall is between 750 and 1750 mm with a uniform distribution in the south grading to a marked summer maximum in the north (Boland *et al*. 1992).

The species grows on a wide range of soils with best development on these that are slightly moist but well drained and of moderately heavy texture such as those derived from shales. It occurs very commonly on sandstone sites. *C. citriodora* also occurs on valley slopes or on ridges if the soil is not too dry (Boland *et al*. 1992).

Potential Products/Uses

The timber from natural stand is good quality and extensively used for heavy and general building construction, flooring and sleepers. It is a very good timber for preservative-treated poles and tool handles. The wood has also been used for plywood (Hills and Brown 1978).

Commercial Viability

Considerable variation has been recorded in the natural stands and there may be several taxa within the species. *C. citriodora* is a tall tree and when mature has a long, clean, symmetrical boles. Young stands often have a high proportion of forked stems and relatively narrow crowns (Hills and Brown 1978).

Eucalyptus argophloia **Blakely (Queensland Western White Gum)**

Growth Characteristics

E. argophloia is a medium-sized to tall tree, with good form, attaining 40 metres in height and 1 meter in diameter at breast height (Boland *et al*. 1992).

Distribution and Growth Conditions

Eucalyptus argophloia occurs in either a woodland or open-forest formation. The species has a very small natural occurrence in an area from Burncluith to Burra Burri in southern Queensland (Boland *et al*. 1992).

The altitudinal range is 300 – 340 metres. The climate is warm sub-humid, with the mean maximum temperature of the hottest month around 32°C and the mean minimum temperature of the coldest moth around 4°C. Some frosts may occur. The annual rainfall is around 700 mm with a notable summer maximum (Boland *et al*. 1992).

This species grows on and around the edges of flats in country of low topographic relief. The soils are red loams or grey-brown clays and clay loams of moderate fertility (Boland *et al*. 1992).

Potential Products/Uses

The wood is deep red with a strong, hard texture and is durable. The density has not yet been researched and is unknown. Major demands for the wood are in the local markets and the wood is used for fencing and general construction (Boland *et al*. 1992).

Eucalyptus microcorys F. Muell. (Tallowwood)

Growth Characteristics

Eucalyptus microcorys is a medium-sized to very tall forest tree commonly attaining 35 – 60 metres height and a diameter at breast height of 1 – 2 metres. The form is generally good with straight, clear boles to two-thirds of the total height (Hills and Brown 1978; Boland *et al*. 1992).

Distribution and Growth Conditions

The species is common in tall open-forests mainly on rainforest fringes (Boland *et al*. 1992).

The altitudinal range is from near sea level to around 750 metres. The climate is mostly warm humid, with the mean maximum temperature of the hottest month in the range 24 – 31°C and the mean minimum of the coldest month around 0 – 10°C. Frosts are rare and very light in the low coastal areas, while in the colder sites heavy frosts may be experienced. Mean annual rainfall is around 1000 – 2000 mm with a distinct summer maximum, particularly in the north of its range (Boland *et al*. 1992).

E. microcorys prefers fertile soils, but will grow on rather poor sands if sub-soil moisture is adequate. The best development is reached in fertile gullies on the margins of rainforest (Boland *et al*. 1992).

Potential Products/Uses

The species is less satisfactory for pole production than *E. cloeziana* (Hills and Brown 1978). The colour of the wood is yellowish brown with a moderately coarse texture. The grain is greasy and usually interlocked which makes gluing difficult. Although, the wood is hard, strong and extremely durable. The density is about 1000 kg m^{-3}. The wood is valued for flooring, decking, heavy engineering construction, posts, poles, crossarms, sills and railway sleepers. Boland *et al*. (1992) considers it as one of the best native hardwood timbers.

Commercial Viability

Eucalyptus microcorys has slow initial growth, therefore other species are favoured due to regeneration rates (Hills and Brown 1978).

Eucalyptus dunnii **Maiden (Dunn's White Gum)**

Growth Characteristics

Eucalyptus dunnii attains height of 50 metres and diameter at breast height of 1 – 1.5 metres with a clear stem up to 30 – 35 metres. In more open-grown conditions the crown is wide spreading and heavily branched (Hills and Brown 1978; Boland *et al*. 1992).

Distribution and Growth Conditions

E. dunnii has a distribution restricted to north-eastern New South Wales and southern Queensland (Hills and Brown 1978). The species forms a tall open-forest (Boland *et al*. 1992).

The altitudinal range is 300 – 750 metres. The climate is warm humid, with the mean maximum temperature of the hottest month in the range of 27 – 30°C and the mean minimum of the coldest month around 0 – 3°C. Frosts occur each winter. The mean annual rainfall is around 1000 – 1750 mm with a summer maximum (Boland *et al*. 1992).

E. dunnii is mainly found in the bottom of valleys and on the lower slopes of hills and escarpments. It also grows high on ridges in basaltic soils around he edges of rainforest. This species prefers moist, highly fertile soils, particularly those of basaltic origin, but will also grown on these derived from sedimentary rocks, especially the more freely drained shales (Boland *et al*. 1992).

Potential Products/Uses

Wood is used for light construction purposes (Hills and Brown 1978).

Commercial Viability

E. dunnii is more frost resistant than other species which are equally as productive in the same habitat, for example *E. grandis*. The tree is prone to defoliation by scarab beetles, therefore the wood is mainly used for pulp (Hills and Brown 1978).

Corymbia henryi **(S. T. Blake) K.D.Hill & L.A.S Johnson (Large-leaved Spotted Gum)**

A broader-leaved taxa of *C. citriodora* has been raised to a specific status as *C. henryi*, therefore this section should be read in conjunction with the description of *C. citriodora* (Blake 1977).

Growth Characteristics

There was no specific information found addressing this attribute.

Distribution and Growth Conditions

C. henryi is a medium-sized to tall forest tree with a restricted distribution from Brisbane to Coffs Harbour on the north coast of New South Wales (Brooker and Kleing 1993).

There was no specific information found addressing the altitudinal range and site conditions for the species.

The climate is warm humid to warm sub-humid (Brooker and Kleing 1993).

C. henryi grows well on moist, well drained soils of moderately heavy texture (Hills and Brown 1978).

Potential Products/Uses

The sap wood is white and the heart wood is brown. The grain is straight or interlocked and occasionally wavy with a density around 1000 kg m^{-3}. The wood is easily worked and may be used for bridge construction, tool handles, framing, flooring and case manufacture (Brooker and Kleing 1993).

Eucalyptus resinifera **Smith (Red Mahogany)**

Growth Characteristics

Eucalyptus resinifera is well developed in the Gympie district in southern Queensland. It is considered a medium sized to tall tree reaching heights of up to 45 metres with a diameter at breast height of 1–1.5 metres. The trees form is good, with a clear, straight stem for up to two-thirds of the total tree height (Boland *et al.* 1992).

Distribution and Growth Conditions

Eucalyptus resinifera is usually found in open-forest to tall-open forest formation (Boland *et al.* 1992).

The altitudinal range is usually from near sea level to 300 m but is known to reach up to 1000 m (Boland *et al.* 1992).The climate is warm humid with a mean maximum temperature of the hottest month ranging from 24–34°C and the mean minimum of the coldest month ranging from 1–19°C. Frost are absent in the low range and coastal areas, with less than 10 per year occurring on the higher altitude sites (above 300 m). Mean annual rainfall varies from 800–2500 mm (Boland *et al.* 1992).

The species grows on a wide range of soils but show best form on soils of volcanic origin like the light, fertile sandy podsols and the deep red loams. It is generally found on the lowland slopes, in valleys and in sheltered flats (Boland *et al.* 1992).

Potential Products/Uses

The timber is red in colour with the sapwood being slightly paler and susceptible to borer attack. It is a moderately coarse-textured, easily worked and has good finish. This species is a durable one, with a density of about 960 kg m^{-3} , it is used for flooring, cladding, panelling, sills, bridge decking and general construction purposes (Boland *et al.* 1992).

Commercial Viability

This species grows a little slower than *E. grandis*, but is still faster growing than some of the other pole species, and makes a good coppice crop. It is grown as a plantation species in a small program in Western Australia, and could be considered for limited planting in the eastern states (Hills and Brown 1978).

Eucalyptus acmenioides Schauer (Yellow Stringybark or White Mahogany)

Growth Characteristics

E. acmenioides can be a very tall tree to 60 metres in height and over 1 meter in diameter at breast height. On drier sites the tree is less productive and may not exceed 25 metres in height (Boland *et al*. 1992).

Distribution and Growth Conditions

Eucalyptus acmenioides is mainly a species of open-forest to tall open-forest formation. It is commonly found on the drier ridges in coastal areas (Boland *et al*. 1992).

The altitudinal range is from near sea level to about 1000 metres. The climate is mostly warm humid to warm sub-humid with the mean maximum temperature of the hottest month in the range 26 – 32°C and the mean minimum temperature of the coldest month around 2 – 13°C. A few light frosts can be tolerated by the species. The mean annual rainfall is about 700 – 1700 mm with a slight summer maximum in the far south of the range grading to a very distinct summer maximum in the north (Boland *et al*. 1992).

This species grows on a wide range of topography. In New South Wales it commonly occurs on hills and ridges below 300 metres in altitude and extends to the plateau on hills of the Great Dividing Range in Queensland (Boland *et al*. 1992).

Potential Products/Uses

The wood is yellow-brown to brown, fine textured, hard, strong and very durable and termite resistant. With a density of about 990 kg m^{-3} the timber is utilised for poles, sleepers bridge and wharf construction, stumps, plates, flooring, joists and weatherboards (Boland *et al*. 1992). The wood is also valued in hardboard manufacture (Hills and Brown 1978).

Eucalyptus grandis W. Hill (Rose Gum)

Growth Characteristics

Eucalyptus grandis stands occur in southern Queensland from the NSW boarder to Bundaberg. The tree can reach heights of 75 metres in height with a diameter at breast height exceeding 3 metres. Tree form is considered excellent, displaying a clear, straight bole for two thirds to three quarters of the total height (Boland *et al.* 1992).

Distribution and Growth Conditions

Eucalyptus grandis is generally found in tall open-forest formation. Associated eucalypts species include *E. intermedia, E. pilularis, E. microcorys, E.* resinifera and E. saligna.

The altitudinal range varies from near sea level to around 600 m in the main distribution (including southern Queensland). The climate is mostly warm humid with a mean maximum temperature of the hottest month around 24–30°C and the mean minimum of the coldest month around 3–8°C. The species can experience light frosts in the higher altitude areas. The mean annual rainfall for the species ranges from 1000–3500 mm (Boland *et al.* 1992).

Stands grow best on deep loamy soils of alluvial or volcanic origin which display high moisture and good drainage. They are found on the flats or lower slopes of the deep and fertile valleys of the distribution. Sometimes stand occur around or just in the fringes of rainforest areas.

Potential Products/Uses

The wood is pink to red in colour, borer resistant, coarse textured, moderate in strength and durability. It has a variable density that ranges from 700–800 kg m^{-3}. It has uses in general construction, joinery, plywood, panelling, boat building and flooring (Boland *et al.* 1992).

Commercial Viability

E. grandis plantations are viable in southern Queensland on deep, freely drained and fertile sites in the humid and subtropical or the warm temperate areas. The mean annual rainfall is ideally in excess of 1000 mm, with minimum temperatures above -3°C. In the tropics, planting should be on the low altitude sites. Its susceptibility to damage from chrysomelid beetles and other insect pests to plantations established on grassland sites is a disadvantage. Degrade in the sawn product is also a disadvantage, although it is a very good species for pulp (Hills and Brown 1978).

Eucalyptus tereticornis **Smith (Forest red gum, Blue gum, Red iron gum)**

Growth Characteristics

E. tereticornis has an extensive range over the eastern coast of Australia. It has a mainland latitudinal range of 15–38°S. It is considered a medium tree, reaching heights of 50 metres and a diameter at breast height of up to 2 metres. Tree form is good, with a clear bole for over half of the total height. This species has characteristic steeply inclined major limbs.

Distribution and Growth Conditions

This species occurs as an open-forest formation. It is also found as scattered trees on alluvial flats, lower slopes of hillsides, mountain slopes and plateaux (Boland *et al.* 1992). It is found associated with a range of other eucalypt species.

The altitudinal range varies from sea level to around 1000 m. Due to the extensive coverage, the climate ranges over a number of conditions, from warm to hot subhumid to humid and occasionally wet. The mean maximum temperature of the hottest month is around 24–36°C and the mean minimum of the coldest month is around 1–19°C. Some inland stands can tolerate numerous frosts. The mean annual rainfall varies from 650 to in excess of 3000 mm (Boland *et al.* 1992).

E. tereticornis prefers rich alluvial soils or the sandy or gravelly loams which are moist, but well drained (Boland *et al.* 1992).

Potential Products/Uses

The sapwood is yellow with the heartwood red, timber is susceptible to borers, fine textured, hard and strong. It is a durable timber, with a density of 1100 kg m^{-3} . *E. tereticornis* is used for heavy engineering construction, railway sleepers, piles, poles and posts.

Commercial Viability

E. tereticornis is fairly sensitive to frost and grows best on well drained soils. It has not been planted for wood in Australia but it could have a place in eucalypt afforestation projects in northern Australia (Hills and Brown 1978).

Summary of Hardwood characteristics

Table B1. Summary of Biophysical attributes for Hardwood Species

Species	Ht (m)	Max DBH	Stem Form	Stand	Mean Max Hottest	Mean Min Coldest	Mean Ann. RF (mm)	Altitude (m)
E. cloeziana	55	2	Excellent	TOF/W	29–34	5–18	550–2300	75–950
E. pilularis	70	3	Excellent	TOF	24–32	5–10	900–1750	0–600
C. citriodora	45	1.3	Straight	TOF–OF	25–30	1–8	750–1750	0–950
E. argophloia	40	1	Good	OF–W	32	4	700	300–340
E. microcorys	60	2	Good	TOF	24–31	0–10	1000–2000	0–700
E. dunnii	50	1.5	Good	TOF	27–30	0–3	1000–1750	300–750
C. henryi	Similar to *C. citriodora*							
E. resinifera	45	1.5	Good	TOF–OF	24–34	1–19	800–2500	0–1,000
E. acmenoides	60	1	Good	TOF–OF	26–32	2–13	700–1700	0–1,000
E. grandis	75	3	Excellent	TOF	24–30	3–8	1000–3500	0–600
E. tereticornis	50	2	Excellent	OF	24–36	1–19	650–3000	0–1000

Table B2. Summary of Soil requirements for Hardwood Species

Spp	Geology	Fertility	Drainage	Depth	Texture
E. cloeziana	Metasediments	L–M	Good	Mod	Coarse (metasediments or loams of Volcanic origin
E. pilularis	Siliceous	L	Good	Deep	Sandy loams or loams
C. citriodora	Shale or sandstone		Good		Mod heavy (shales)
E. argophloia		M			Red loams/grey-brown clays/clay loams
E. microcorys		H	Good		
E. dunnii	Basalt or sedimentary rock (shale)	H	Good		
C. henryi			Good		Mod heavy
E. resinifera	volcanic	H			Wide range of soils but best on light, fertile sandy podsols and deep red loams
E. acmenoides					
E. grandis	Alluvium/ volcanic	H	Good	Deep	Loams
E. tereticornis	Alluvium	H	Good		Alluvium or sandy or gravelly loams

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Softwoods

Araucaria cunninghamii Aiton ex D. Don (Hoop Pine)

Growth Characteristics

Araucaria cunninghamii attains heights of up to 60 metres with a diameter of 0.6 to 1.9 metres at breast height. Its form is characterised by a long straight bole typically with no branches for up to two thirds of the stem. Tapering of the bole tends to be minimal giving the impression of a consistent diameter (less conical in shape). Crown is distinctively open, with dark green foliage occurring towards the ends of branches (Boland *et al*. 1992).

Distribution and Growth Conditions

A. cunninghamii is found from the Clarence River, New South Wales to near Bundaberg, Queensland (Boland *et al*. 1992).

The altitudinal range is from near sea level to around 1000 metres. The climate is mostly warm humid, with the mean maximum temperature range of the hottest months around 27 – 30°C. The mean minimum of the coldest month ranges from 1 – 7°C. The species is frost resistant. The mean annual rainfall is 1000 – 2000 mm, with a distinct summer maximum in the north of the range (Boland *et al*. 1992).

A. cunninghamii grows on a variety of parent materials where the soils range from krasnozems, red earths or humus-enriched regosols to dark grey self-mulching soils. The species grows best on soils which are well drained and aerated (Boland *et al*. 1992).

Potential Products/Uses

The wood is white to light brown with a fine texture, which is low in strength and durability. The density of the wood is about 530 kg m^{-3}. The advantage of this timber is that it is uniform in appearance and properties. *A. cunninghamii* wood is used extensively for plywood and veneer. The wood is also used for matchboxes, broom handles, printer's blocks, boat building and furniture (Boland *et al*. 1992).

Commercial Viability

A. cunninghamii plantations perform best on natural *A. cunninghamii* sites in south east Queensland. The most productive sites are those on red volcanic soils near the Atherton Tablelands and Gympie regions (NPI 1996).

Research and Development on *A. cunninghamii*

- Sun, D., Dickinson, G.R. and Bragg, A.L. (1996) *Effect of cattle grazing and seedling size on the establishment of Araucaria cunninghamii in a silvo-pastoral system in northeast Australia.* Journal of Environmental Management (49)

F1 Hybrid (slash x caribaea)

Growth Characteristics

Properties are similar to that of both slash and caribaea, that is fast early growth.

Distribution and Growth Conditions

Exists on poorly-drained sites within southeast Queensland (Harding and Hagan 1990).

Potential Products/Uses

The wood has a higher density than most softwoods, along with being finely branched. The sawn timber from these exotics has mechanical properties toward the top of the range for softwoods. The wood is suitable for structural applications and as preservative treated rounds (NPI 1996).

Commercial Viability

This hybrid is now used in all exotic pine planting in southern Queensland plus the more poorly drained sites in central Queensland (NPI 1996). The expansion of the planting of this species onto intermediate drained sites is currently being considered.

Research and Development on F1 Hybrid (slash x caribaea)

- Harding, K. J and Hagan, M. T. (draft 1990) *Variation in wood properties of 24.5-year-old Slash X honduras caribbean pine F1 hybrid stems compared to their parental species properties when grown on a well-drained site.* Paper prepared for QFS Forest Development Branch F1 hybrid review seminar, Gympie 9/10 October 1990

Pinus caribaea var. hondurensis (Caribbean Pine)

Growth Characteristics

Pinus caribaea has proven to be mores suited to tropical areas and is a versatile species. This species is the dominant species planted on the coast of Queensland. (NPI 1996).

Potential Products/Uses

The wood has a higher density than most softwoods (575 kg m^{-3}) along with being finely branched. It is low in durability and light in colour. The sawn timber from these exotics has mechanical properties toward the top of the range for softwoods. The wood is suitable for structural applications and as preservative treated rounds (NPI 1996).

Commercial Viability

P. caribaea is more productive than *P. elliottii,* however stem form and susceptibility to wind damage can cause problems (NPI 1996).

Pinus elliottii var. elliottii (Slash Pine)

Growth Characteristics

Pinus elliottii is the major exotic plantation species on the coastal lowlands of southern Queensland (NPI 1996). Suitable for the coastal plain form Bundaberg south. *Pinus elliottii* is frost hardy and will tolerate a variety of different soils if drainage is moderate (QDPI 1991).

Potential Products/Uses

The wood has a higher density than most softwoods, along with being finely branched. The sawn timber from these exotics has mechanical properties toward the top of the range for softwoods. The wood is suitable for structural applications and as preservative treated rounds (NPI 1996).

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APPENDIX C Soil Attributes for Land Resource Area Maps and Moreton Geology Sheet

Inland Burnett LRA's

LRA	Fertility	Permeability	Depth	Texture
Floodplains	5–9	5–9	8–10	5–10
Terraces	1–4	3–9	8–10	7–9
Relict alluvial plains	3–6	3–6	5–7	8–9
Undulating plains	5–10	5–9	6–8	8–10
Basalt rises	6–10	5–8	7–9	8–9
Volcanic uplands	3–7	7–8	3–6	8–9
Red tablelands	3–8	6–9	8–10	6–8
Upland sediments	3–5	2–4	3–6	6–7
Granite hills	3	2–4	2–8	4–7
Ranges	3–8	3–7	1–6	3–7

Port Curtis – Wide Bay LRA's

LRA	Fertility	Permeability	Depth	Texture
Stream alluvia	3–8	3–9	8–10	4–10
Coastal dunes and sand plains	1–4	4–10	8–10	2–3
Swamps, estuaries and tidal flats	5	1	8–10	3–8
Basic volcanics	3–10	4–8	7–10	8–10
Consolidated sediments				
–Plains	2–8	2–8	6–10	6–10
–Plains and mountains	2–6	5–7	5–8	6–9
–Mountains	2–6	7–8	3–7	6–8
Volcanic/sedimentary complexes	3–6	7–8	2–9	5–8
Acid/intermediate volcanics	3–6	3–7	2–7	6–8
Granite				
–Plains	2–6	2–5	5–8	7–9
–Plains and mountains	2–6	5–8	3–8	5–8
–Mountains	2–6	7–8	2–8	5–8
Metamorphic	2–6	3–9	2–7	6–8

Moreton Geology

	Attribute			
Stratigraphic Unit	**Frt**	**Perm**	**Dpth**	**Text**
Alluvium	8	5	10	7
siliceous sand	3–7	6–10	7–10	3–4
saline alluvium	4–5	1	1	6
Coarse acid igneous (granites)	3	7	5	4
Fine acid igneous	2–3	3	2	3
Coarse intermediate igneous (granodiorite)	4	7	6	6
Fine intermediate igneous	6–7	5	4	7
Coarse basic igneous	7–8	4	6	8
Fine basic igneous	8.5	4	6.5	8
Ultra basic igneous (serpentinites)	6	3	4	9
Labile sedimentary	3–9	3	4–5	6–8
Quartzose sandstones	3	7.5	5	4
Metasedimentary	4	4.5	3	5

APPENDIX D Soil Plantation Suitability Attributes

Inland Burnett LRA's

LRA	HP	Pin	Ea	Cc	E3
Floodplains	U	L	H	L	U
Terraces	U	U	M	L	U
Relict alluvial plains	U	U	L	U	U
Undulating plains	L(U–M)	U	M	L	U
Basalt rises	M(U–H)	M	H	H	H
Volcanic uplands	U (occ. M)	L	H(occ. L)	L(occ. U–M)	U
Red tablelands	M	M	H	H	M
Upland sediments	U(occ. M)	L	M	M	L(occ. M)
Granite hills	U	U	L	L	U
Ranges	U(occ. M)	L	U	L(occ. M)	L(occ. H)

Port Curtis – Wide Bay LRA's

LRA	HP	Pin	Ea	Cc	E3
Stream alluvia	M(U–H)	M(U–H)	M(U–H)	M(U–H)	M(U–H)
Coastal dunes and sand plains	U	M with fert	U	U	M with fert
Swamps, estuaries and tidal flats	U	U	U	U	U
Basic volcanics	H	H	H	H	H
Consolidated sediments					
–Plains	U	M(M–H)	U	L	U
–Plains and mountains	U	M	U	M	U
–Mountains	U	M	U	M	L
Volcanic/sedimentary complexes	H	M	H	H	H
Acid/intermediate volcanics	H	M	H	H	H
Granite					
–Plains	U	L	U	L	U
–Plains and mountains	L(U–M)	L	L	M(L–H)	L(U–H)
–Mountains	M	L	U	M	M
Metamorphic	M(U–H)	L	L	M(U–H)	M(U–H)

Moreton Geology

Stratigraphic Unit	Suitability by Species				
	HP	Pin	Ea	Cc	E3
Alluvium	M(L–M)	H(M–H)	H(M–H)	H(M–H)	M(M–H)
siliceous sand	L(L–M)	M (M–H)	L	M(M–H)	M(M–H)
saline alluvium	U	U	U	U	U
Coarse acid igneous (granites)	L(L–M)	M(L–M)	L(L–M)	M(M–H)	M(L–H)
Fine acid igneous	U(U–M)	U	L(L–M)	M(L–H)	L(L–M)
Coarse intermediate igneous (granodiorite)	M(M–H)	M(L–M)	M(L–H)	H(M–H)	M(M–H)
Fine intermediate igneous	L(L–M)	L (L–M)	M(L–H)	H(M–H)	L(L–M)
Coarse basic igneous	H(M–H)	M(L–M)	H(M–H)	H(M–H)	H(M–H)
Fine basic igneous	H(M–H)	M(L–M)	H(M–H)	H(M–H)	H(M–H)
Ultra basic igneous (serpentinites)	U	U	U	U	U
Labile sedimentary	M(U–H)	M(U–H)	M(L–H)	M(L–H)	M(U–H)
Quartzose sandstones	L(L–M)	M(L–M)	M(L–H)	H(M–H)	L(L–M)
Metasedimentary	L(L–M)	M(L–M)	M(L–H)	H(M–H)	L(L–M)

Species	Code
E.grandis E.cloeziana E.pilularis	E3
Araucaria cunninghamii (hoop pine)	HP
Corymbia citriodora	Cc
E.argophloia	Ea
Pinus spp	Pin

APPENDIX E Soil Plantation Suitability Attributes and Rainfall Decision Matrices

E.grandis E.cloeziana E.pilularis

Rainfall	Soil suitability			
	High	Medium	Low	Unsuitable
>1300mm	**H**	**M**	**L**	**U**
>1000mm	**M**	**M**	**L**	**U**
>800mm	**M**	**L**	**U**	**U**
<800mm	**U**	**U**	**U**	**U**

E.argophloia

Rainfall	Soil suitability			
	High	Medium	Low	Unsuitable
>1300mm	**U**	**U**	**U**	**U**
>1000mm	**L**	**L**	**L**	**U**
>800mm	**H**	**M**	**L**	**U**
<800mm	**M**	**M**	**L**	**U**

Corymbia citriodora

Rainfall	Soil suitability			
	High	Medium	Low	Unsuitable
>1300mm	**H**	**M**	**L**	**U**
>1000mm	**H**	**M**	**L**	**U**
>800mm	**M**	**M**	**L**	**U**
<800mm	**M**	**L**	**L**	**U**

Pinus spp

Rainfall	Soil Suitability			
	High	Medium	Low	Unsuitable
>1300mm	**H**	**M**	**L**	**U**
>1000mm	**M**	**M**	**L**	**U**
>800mm	**L**	**L**	**U**	**U**
<800mm	**U**	**U**	**U**	**U**

Araucaria cunninghamii (hoop pine)

Rainfall	Soil suitability			
	High	Medium	Low	Unsuitable
>1300mm	**H**	**M**	**L**	**U**
>1000mm	**M**	**M**	**L**	**U**
>800mm	**M**	**L**	**U**	**U**
<800mm	**U**	**U**	**U**	**U**

Suitability	Rating	High	Medium	Low	Unsuitable
	Code	**H**	**M**	**L**	**U**
	MAI (m^3/ha/yr)	>20	15–20	10–15	<10

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