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The Influence of Forest Management on Sawn Timber Recovery and Value in Cypress Pine

A report for the RIRDC/Land & Water Australia/FWPRDC/MDBC Joint Venture Agroforestry Program

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Foreword

The white cypress industry is relatively small by Australian and international standards and is based on the white cypress pine (*Callitris glaucophylla*), a native conifer with distinctive timber properties. The total yearly harvest in New South Wales and Queensland of between 200 and 250 thousand cubic metres, principally from State forest, is shared by a relatively large number of processors producing a variety of products and selling to a range of markets. The major part of the forest resource extends through the sub-humid zone of New South Wales and southern Queensland. Within this area, the milling of white cypress is an important industry, providing jobs and cash flow into the regional economies.

In comparison to many other forest types, productivity is low and tree size is relatively small. Harvesting is predominantly for sawlogs with most logs being processed into timber framing or flooring. In the past much of the sawn product was sold on the domestic market. In recent years, white cypress, the commonly used trade name, has been replaced in the house frame market by material from exotic pine plantations and this has stimulated the industry to develop new markets. Some of these new markets have been found in the higher value international demand for feature timber where the unique properties of white cypress timber, i.e., aesthetic appeal, termite resistance, distinctive odour and mid-range density provide a market edge.

To maintain these markets requires high-grade sawn product, which in turn requires high-grade logs. Anecdotal evidence from a number of sawmillers suggested that the high grade logs are available from the more intensely managed ‘regrowth’ forests where a history of silvicultural management (thinning and harvesting) is providing a uniform, high quality log.

Much of the timber currently harvested is from State owned lands and this is unlikely to increase in volume. Moreover, current reviews of this resource may well reduce the annual harvest through conversion of Crown forest area to conservation purposes. In the past, large volumes of timber were harvested from private land; however, this has been declining for many years. In New South Wales, the private cut forms less than 10% of the total harvest while in Queensland it represents approximately one quarter. Future harvest levels from private land are uncertain due to extensive land clearing in recent years and uncertainty surrounding vegetation management legislation.

Thus, for the industry to maintain or expand current levels of harvest it will have to look for resource on lands other than Crown land and a stimulus is required to encourage private landholders to manage their forest areas productively. Few landholders in the sub-humid zone have seriously practiced farm forestry in the past. Most capitalise on the available standing timber when the economic need arises and fail to adequately manage their forest in the interim period thereby substantially decreasing potential productivity and quality. As time progresses, there are compelling reasons for many private landholders to take a second look at forest management and for the white cypress processing industry to support this.

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This report, an addition to RIRDC’s diverse range of over 1200 research publications, forms part of our Agroforestry and Farm Forestry R&D program, which aims to integrate sustainable and productive agroforestry within Australian farming systems.

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Contents

Executive summary

This project investigated aspects of white cypress pine forest management and utilisation in order to promote retention and management of white cypress pine forests for high value timber production. Three principal areas were addressed, *viz*:

- A review of available information on the ecology, distribution and marketing of white cypress[1]
- A sawing study to quantify links between forest management, green-off-saw (GOS) and dried graded timber recovery, and
- An investigation and review of the insect pests and decay fungi of white cypress relating to timber production.

Ecology, distribution and management

White cypress (*Callitris glaucophylla*) is a native conifer principally occurring in the sub-humid zone in a band stretching from southern New South Wales (NSW) into approximately central Queensland. It grows as a small to medium tree and occurs naturally in a range of vegetation associations, either as a pure stand or as a subdominant in mixed forests. It is fire sensitive, however, once established, litter loads are much reduced and with the exception of severe wildfire, fires are generally very mild and do not carry into the crowns or in the understorey.

The species is known to regenerate prolifically when good seed years coincide with optimal seasonal conditions. When this occurs, very dense stands or ‘wheatfield’ regeneration can establish. Regeneration in New South Wales tends to rely more on this method than in Queensland where small amounts of regeneration occur on a more regular basis. The resultant stand types are also different with more ‘uneven-aged’ stand structures occurring in Queensland although some of this is influenced by management. In the absence of silvicultural intervention, the dense regeneration tends to develop into a stand condition termed ‘lock-up’ and become moribund where trees are in a stage of intense competition with very low or nil growth and low rates of mortality.

Silvicultural regimes have been developed in both states to manage white cypress pine for timber production. In New South Wales, a ‘shelterwood’ system has been developed where harvesting is carried out in two stages to promote regeneration. Under this regime much of the volume is removed in a single harvest leaving seed trees and there is a relatively long growth interval between harvests. Stands tend towards a more ‘even-aged’ or ‘two tier’ structure. In Queensland, a ‘single tree selection’ or ‘selective harvesting’ approach has been taken favouring an ‘uneven-aged’ structure where harvesting intervals are relatively short and a range of diameter classes are always present in the stand. These two management regimes have developed in response to regeneration patterns in each state. In both cases, management of cypress pine results in relatively high productivity, up to or in some cases exceeding 1 m^3 / ha / yr in high quality stands, in comparison with unmanaged stands where negligible growth is often recorded.

Inventory information for State forest and some leasehold areas is comprehensive and this provides state agencies with accurate estimates of overall productivity from which to manage harvest levels. Distribution of white cypress outside of State forest and some leasehold land has been mapped by remote sensing and is therefore an estimate only. There is no qualifying information from this mapping in terms of either forest condition or stand composition. Of a total area of approximately 4.1 M ha of forest containing or dominated by cypress pine in both States, approximately 1.3 M ha is on freehold land (870,000 ha in Queensland and 430,000 ha in New South Wales). While much of this is likely to be relatively unproductive, the potential freehold resource is quite significant.

[1] White cypress is the commonly used trade name for white cypress pine.

Pests and disease

Major pests of cypress pine include jewel beetles, Durabilla white grub, cypress bark weevil and termites. The major insect pests of white cypress are listed and their distribution, damage type and life cycles described in this report. Implications for forest management and timber processing are also discussed. In general, pests and disease of white cypress did not have a major influence on sawn recovery in this study. Some insects, in particular beetles, have an influence on both aesthetics and sawn recoveries, and thus influence utilisation and marketing of white cypress.

Sawing study

To test and quantify the relationship between forest management and timber recovery, both green-off-saw and graded, a sawing study was conducted where logs from three different management intensities, *viz*, managed, partially managed and unmanaged, from each of three geographically different localities, were harvested and processed. Two localities were selected in Queensland and one in New South Wales. From the processor's perspective, larger, defect free logs are desirable due to the higher recovery overall and in particular the higher volume of large piece sizes produced. Smaller logs generally equate to lower recoveries and a higher proportion of narrow boards (75mm or 3 inch) for which there is currently limited market opportunity.

A total of 270 trees were harvested, consisting of 30 representative trees from nine sites in three localities, to produce a total sawlog volume of 67 m^3. These logs were sawn by a commercial operation in southern Queensland to produce green sawn, 25mm thick boards in 75mm, 100mm, 125mm and 150mm widths.

Boards 100mm and wider (nominally 4-inch, 5-inch and 6-inch) were kiln-dried, dressed to standard tongue and groove flooring profiles and graded to export specifications (i.e. moisture content 6-9%, North American flooring grade). The 75mm wide material (nominal 3-inch) was green-dressed to a pencil-round profile and graded to specifications for southern Australian markets, principally Victoria.

Harvested volumes from each site ranged from 4.33 m^3 to 15.19 m^3. Green-off-saw recoveries ranged from 33.8% to 42.1%, depending on original source. The recovery study showed that the relationships between tree size and sawn recoveries (green-off-saw and dried graded) were influenced by past silvicultural management on some sites more than others. In general, past intensive management produced an increase in both green-off-saw and dried graded recoveries over nil or partial forest management. Some aberrations were apparent and not all variation was due to past management effects. It is suggested that site factors may also influence sawn recoveries.

Introduction

The Australian cypress pine industry is based primarily on white cypress (*Callitris glaucophylla*), a native conifer growing in pure or mixed forests in a band stretching through the western parts of New South Wales (New South Wales) and into southern and central western Queensland. Significant areas of white cypress pine forest also occur in South and Western Australia and in the Northern Territory. These are generally lower quality stands of little value for timber production or comprised of other *Callitris* species of lesser commercial value. Some utilisation of these forests has occurred in the past.

Predominantly, the white cypress (preferred trade name) processing industry is reliant on Crown resource in Queensland and New South Wales where harvesting and varying degrees of forest management for timber production have been practiced for up to 100 years in some areas. The majority of white cypress forest managed for sustainable timber production is regrowth forest resulting from past reservation and silvicultural management. In Queensland significant areas of ‘first cut’ forests are still being harvested and this is usually a mixture of ‘virgin’ and ‘regrowth’ forest on leasehold land. In 1999/2000, approximately 282,000 m^3 (Anon. 2000) of sawlogs were harvested in New South Wales and Queensland making it a relatively small component of total Australian forest harvest. Of this, approximately 80 % was harvested from Crown land and the remaining 20% from private land, mostly in Queensland.

Privately owned resource on freehold land contributes to the annual cut, more so in Queensland than New South Wales; however this has declined over time and is likely to continue to decline. In most cases, decreased harvest levels can be attributed to either loss of the resource through tree clearing, more recently in Queensland, or reduced productivity in remaining stands from past inappropriate management. In many cases, little thought has been given by private forest owners to the value of either standing timber or timber production as an enterprise in favour of or complementing grazing (Male, P. *pers comm.* 2000). Declining harvests are also likely from Crown lands as areas once primarily managed for timber production are reserved for conservation purposes.

The industry is important to the regional economies of many areas, providing employment and a local economic buffer against the periodic drought induced downturns in the extensive grazing industry. In some situations, the viability of rural communities is reliant on maintaining a timber processing industry.

Over recent years, the white cypress industry in both states has undergone a transformation. White cypress had been traditionally sold into the domestic market where it was regarded by the building industry as a relatively low quality product. This was mainly the result of poor marketing, variable product quality and poor industry standards (Anon. 1996). Over the last decade increasing competition from other sectors of the timber industry, such as exotic softwoods from plantations, has displaced domestic markets for white cypress such as green structural framing and forced the need for industry-wide change in both product quality and markets.

Significant market opportunity was developed for high quality feature grade product in both the domestic and international market capitalising on the unique timber properties of white cypress (Swain 1928, Sewell 1997). As well, the natural termite resistant properties have been a strong market feature with an increasing popularity for ‘natural’ products and removal of many of the more toxic residual termiticides from the market place. Thus the increasing demand for feature quality white cypress flooring, panelling, componentry and mouldings has created a demand for better quality logs. This is particularly the case where millers have sought international markets where high product standards and consistency are paramount.

There are many factors influencing timber quality and potential value of timber from native forest. Investigations into aspects of forest management such as regeneration, tree spacing, harvest intensity and fire have produced silvicultural management regimes which aim to maximise timber production.

However, the value of management in terms of improved wood quality and uniformity of product over unmanaged forest is poorly known. Anecdotal evidence from a number of timber processors, based on harvest experience in white cypress, suggested that higher recoveries of sawn and graded timber could be realised from the more intensively managed regrowth forests in contrast to the unmanaged resource. Given the industry changes occurring in the major markets, higher recoveries of graded material are highly desirable.

Historically much of the private resource has had little management input. Silvicultural regimes for cypress forests have been developed principally for the Crown estate and there has been no parallel application of silvicultural regimes on private land. This is in strong contrast to many European nations where there is a strong forest management ethic on private land. One reason for this may be the very long term nature of forestry, in particular white cypress, which does not lend itself to investment by private landholders. Returns are relatively small in comparison to other land uses and less immediate than other enterprises such as cropping or livestock grazing.

This project sought to investigate differences in returns to processors from logs with a past silvicultural management history in comparison to logs from forests with either a partial or no management history. Quantified differences could then form the basis for decision making by both private landholders and Crown forest management agencies on silvicultural management of Cypress Pine forests. Aspects of this project also looked at the distribution of white cypress forests and their ecology and the major pests and decays influencing timber recovery and quality.

Following an initial review of the distribution and ecology of white cypress, three localities were selected for sampling. Within each locality, three sites comprising silviculturally managed, partially managed and unmanaged were sampled. A total of $67m^3$ of white cypress logs were individually tracked through a sawmill and assessed for both green-off-saw and dried, graded recovery. During the field sampling process and in the milling stage, pests and decays and their effect on timber recovery were described.

This report presents the results from this project in three parts, *viz*, ecology and distribution of white cypress, a description of the major pests and decay fungi, and, a sawing study investigating results from management. These are discussed and implications for resource management are drawn.

Objectives

The objectives of this study were threefold. The first objective was to collate available information on the ecology, distribution and management of white cypress. This is to benefit resource managers and landholders in making informed decisions on forest management issues. The second objective involved testing the hypothesis that timber quality and sawn recoveries are influenced by past forest management. The third objective was to provide a description of the principal white cypress pests and diseases which may influence timber quality.

Ecology and distribution

This provides an outline of the ecology, growth habit and distribution of white cypress and collates available information. The climate, soils, forest types, growth habits, management systems and markets were described and available information used to provide maps of the distribution. Remotely sensed GIS information on forest type and distribution was collated from available sources on white cypress forest types in Queensland and New South Wales. In particular, available information on the occurrence and distribution of white cypress forest by tenure and forest type was addressed.

Pests and disease

Survey and describe the major insect and disease problems relating to white cypress timber quality. Current information was collated and field studies and observations were made to quantify and describe effects on timber quality.

Sawing study

This objective examined the issue of timber quality in relation to site, past management and pest and disease. Two localities were selected in Queensland and one in New South Wales for the establishment of sample sites. Within each locality three sample sites were selected, some on private / leasehold land and the remaining on State Forest. These sites reflected a range of management histories. At each site, detailed site, stand and individual tree assessment was undertaken and a representative sample from the stand was harvested for milling. Sample logs were processed and green-off-saw and dried, graded recoveries assessed.

Ecology and distribution

Climatic zone

Principally, white cypress occurs in the sub-humid / semi-arid zone to the west of the range in both Queensland and NSW (Map 1 & 2). Climate varies significantly across the resource ranging from a temperate climate in southern NSW, including the component of the resource extending into Victoria and South Australia, to sub-tropical in inland Qld. In the southern part of the distribution there is a slight winter dominant rainfall ranging to a summer dominant rainfall distribution in the central part of the resource near the Pilliga and into Qld. Rainfall averages are given for four centres across the resource below in Figure 1.

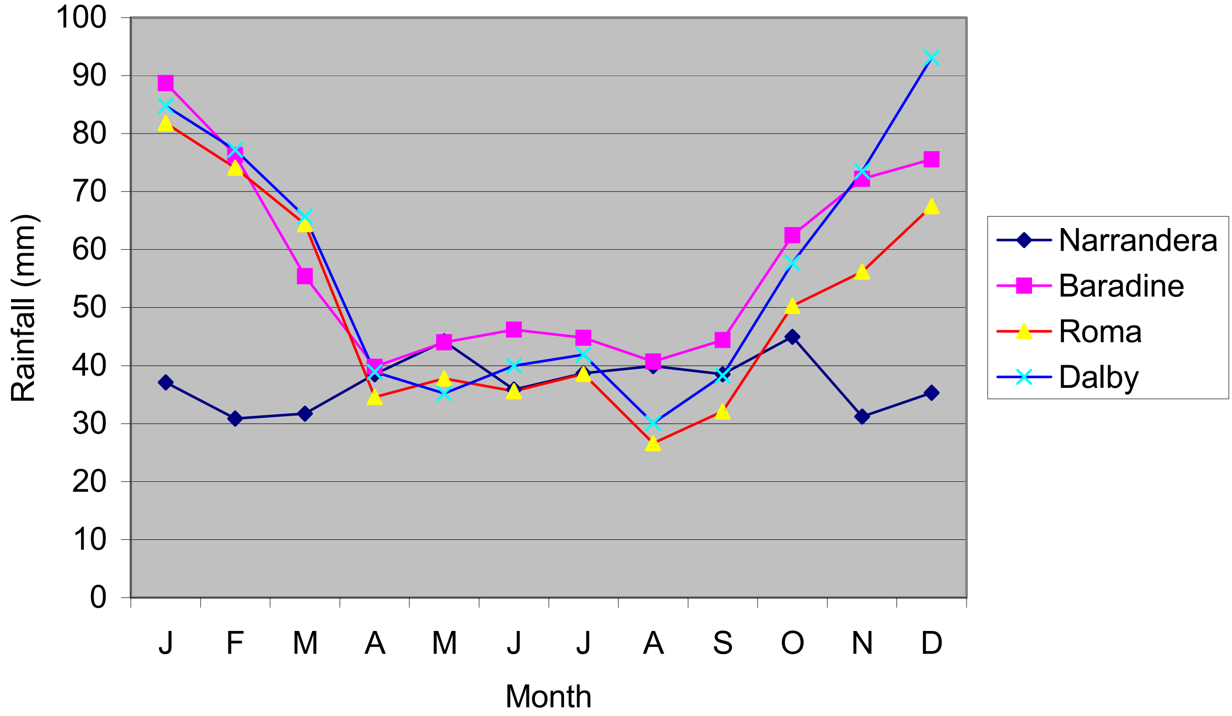


Figure 1. Mean annual rainfall at Narandera, Baradine, Roma and Dalby (from *Bureau of Meteorology – Climate Averages*)

White cypress is known to occur in the rainfall range between 300 – 650 mm / annum (BRS 1997). Johnston (1975) and Male (1974) both referred to the summer dominant rainfall in the Queensland white cypress zone, however, but also recognise seasonal variation and other factors such as soil water holding capacity, evaporation rate and rainfall effectiveness as being major factors in white cypress distribution.

Lindsay (1966) described total annual rainfall in the New South Wales white cypress zone as generally decreasing from north to south and from east to west and this trend continues into Queensland however rainfall decreases significantly from east to west in Queensland and is lower in Roma than in Baradine. Annual rainfall varies between 450 – 750 mm in the main cypress forest areas in New South Wales with the higher rainfall in the north-east and lowest in the south-west of the white cypress areas. Both Lindsay (1966) and Johnston (1975) note the large seasonal variation in rainfall and the regularity of severe droughts in this zone.

Temperature displays a large seasonal and diurnal variation in the white cypress zone. Maximum daily temperatures in the summer months in both Queensland and New South Wales often exceed 40 ^{0} C and in winter frosts are common. Lindsay (1967) notes that temperatures through much of the year are suitable for tree growth in the white cypress zone; however, in the southern parts there is a short period during winter when tree growth ceases. He postulated that cold temperatures may also be a limiting factor in the spread of white cypress towards the east in New South Wales but this is not the case in Queensland where edaphic factors and / or the frequency of fire may have a greater influence on its distribution. Mean daily maximum temperatures are given for the four centres in Figure 2 and there is a progressive cooler trend towards the south as expected in winter with little difference in summer.

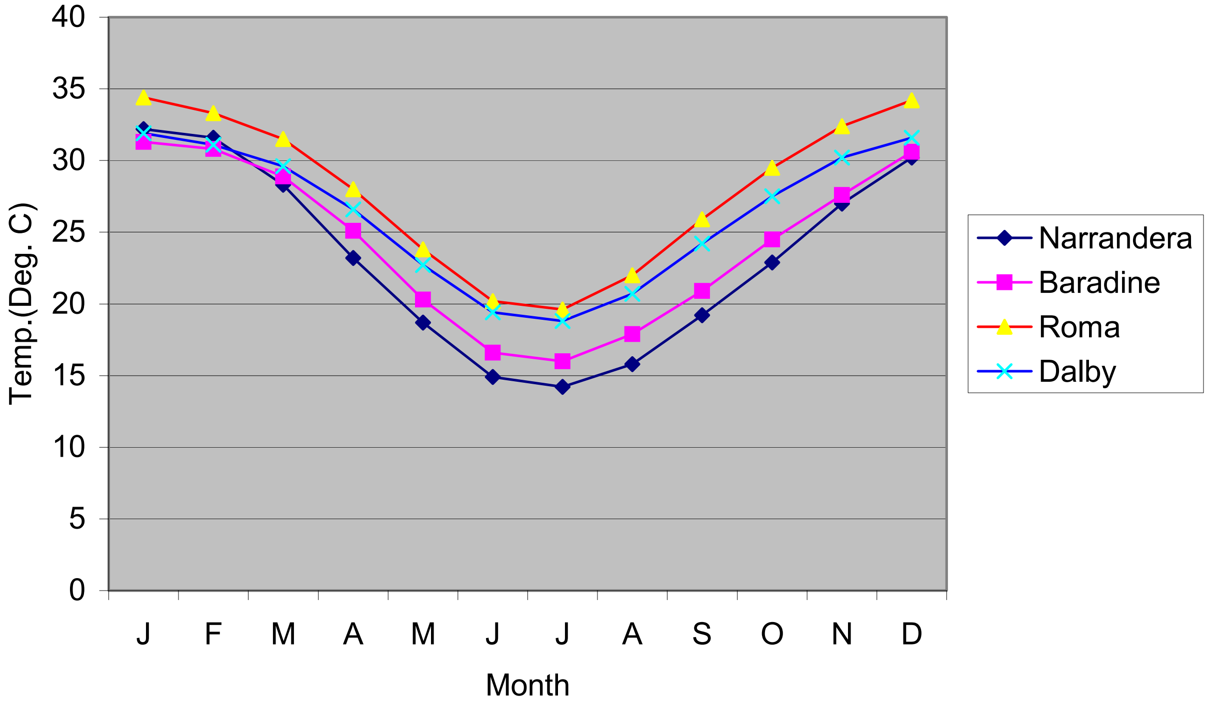


Figure 2. Mean daily maximum temperature for Narrandera, Baradine, Roma and Dalby (from *Bureau of Meteorology – Climate Averages*).

Soils

Throughout the commercial range, white cypress generally favours lighter textured soils but is known to occur over a wide range of soil types. Lindsay (1967), Thompson and Beckmann (nd), Lacy (1973) and Johnston (1975) described the major soil types on which white cypress forests most commonly occur as being generally light textured, often duplex, ranging from loams and deep sands to Red –Brown Earths, Terra Rossa soils and duplex clay soils such as Solodics and Solodised Solonetz (Stace *et al.* 1968). Anecdotal observations indicate that better quality (larger size) white cypress often occurs on the deeper, well drained sandy soils and deep sands (Lindsay 1966, Lacy 1973, Male 1974, Johnston & Jennings 1987, Horn & Robinson 1987).

Forest types

White cypress occurs in a range of species associations as well as in pure stands. The current composition, structure and distribution of much of the white cypress forest has been influenced by European management such as large scale tree clearing, control and often exclusion of fire, selective ‘silvicultural treatment’, harvesting and grazing. It is estimated that current areas of white cypress dominant or co-dominant forest exceed that of pre-European areas (BRS 1997). In regrowth areas and particularly in commercial forests managed for timber production, white cypress often occurs in relatively dense, pure stands as a dominant overstorey with little or no understorey present. More often however white cypress occurs in a mixed forest in association with *Eucalyptus*, *Acacia*, *Allocasuarina* and *Angophora* species.

In Queensland and northern New South Wales common tree species occurring with white cypress include narrow leaved red ironbark *(Eucalyptus crebra),* broad leaved red ironbark *(E. fibrosa),* poplar / bimble box *(E. populnea),* pilliga box *(E. pilligaensis),* carbeen *(E. tessellaris),* smooth barked apple (*Angophora costata subsp leiocalyx),* bloodwoods *(Corymbia bloxsomei, C. trachyphloia, C. dolichocarpa* and others*),* wattle (*Acacia spp)* and she oaks / bull oak (*Allocasuarina spp).* In southern New South Wales other eucalypts occurring with white cypress include yellow box (*E. melliodora),* fuzzy box *(E. conica),* white box *(E. albens),* tumble down red gum *(E. dealbata)* and Blakely’s red gum *(E. blakelyi)* (Boland *et al* 1984, BRS 1997*).* These forest species form a number of forest types with a range of species mixes and structures in response to climatic, biotic and edaphic factors.

Lindsay (1967) attributed the distribution of white cypress in New South Wales to both natural and human (European) influences. Factors he cites include:

- fire frequency and intensity
- soil type and depth
- rainfall – seasonality and intensity
- temperature, particularly minimum temperatures
- height dominance of associated species
- grazing pressure and type.

He described seven generalised forest types covering the white cypress zone of New South Wales:

- white cypress – narrow leaved red ironbark
- white cypress – silver leaved ironbark
- white cypress – red gum
- narrow leaved ironbark – broad leaved ironbark – bloodwood – gum
- white cypress – bimble box
- white cypress – grey box
- Mugga ironbark – red gum – white cypress – black pine

In Queensland, many of the forest types and associations have not been well described however there are consistent association between white cypress, smooth and rough barked apple, ironbark and spotted gum across much of the resource. Young *et al.* (1999) have described a range of regional ecosystems which include white cypress in the Queensland Brigalow Belt bioregion.

Taxonomy

Boland *et al.* (1984) described white cypress as follows; “*Callitris glaucophylla* Thompson and Johnson (formerly *C. glauca* IR. Br. Ex R. Baker & H.G. Smith) is a member of the genus *Callitris* in the conifer family *Cupressaceae*. There are between 12 and 16 species in this genus. It is a small to medium sized tree commonly growing to between 15 and 20 m, however, sometimes reaching 30 m in height. Its normal growth habit is a straight trunk with relatively dense conical crown when younger and a flattened out crown in mature trees. Branches normally occur over the majority of the trunk with density dependent on surrounding vegetation. Open grown white cypress can retain very dense, heavy branching low on the stem. Foliage is a glaucous green in colour and adult leaves are typical of most conifers, small, triangular in section (0.2 – 0.6 mm long) and joined to the stem in alternating whorls except for the leaf tip. Bark is furrowed, fibrous to hard and grey black in colour”.

Growth habit

Following germination, white cypress requires consistently good soil moisture conditions, protection from insolation and protection from fire and grazing to become established. Generally, it is recognised that two consecutive above average rainfall years are required for successful establishment (Lindsay 1967).

Height development is initially quite slow and is dependent to a large extent on competition. Lacy (1973) cited height increments of between 0.3 – 0.45 m / annum during the first few years for well grown stands but he noted that height development may also be extremely slow with examples of 0.5 m over a 17 year period. Height development over longer periods varies with site factors and tree height increments per year of between 0.2 - 0.5 m / annum are common in vigorous, actively growing trees.

Following early establishment, white cypress develops a relatively conical shape in good growing conditions. The crown remains relatively deep, in proportion to total height, during the early phase of height development and towards maturity decreases as a proportion of the height of the tree. Crown shape, depth and density are used as an indicator of the growth potential of a tree and there is evidence suggesting that trees with misshapen or rounded crowns are generally not growing and may have become suppressed (West 1990). Very large old white cypress often display a rounded or flattened crown indicating senescence. Anecdotal evidence suggests that trees which have attained maximum height or reached site potential often exhibit a flattened crown. This is in contrast with more actively growing trees which generally have a conical shaped crown. This feature is often used as a guide in tree marking for harvesting operations. Both Vanclay (1985-1) and Johnston (1975) related height development to site ‘quality’ and stand factors. Vanclay and Henry (1988) developed a ‘Site Form’ function, based on the expected height of a 25 cm DBHOB tree, as an indicator of site ‘quality’.

Diameter increment is also sensitive to competition. The propensity of white cypress to develop into very dense stands with small diameters and a very low tree diameter distribution provides an example of this. Stands with very high densities become ‘locked up’, a stand condition where tree mortality and growth rates are almost negligible (Lacy 1973, West 1989, Henry 1960). Stands in this condition may take considerable time, >100 years, to develop to merchantable size trees (Horne 1990), if at all. This situation is particularly evident in stands resulting from large scale regeneration events and left unthinned.

Horne and Robinson (1987) and Horne (1990) discuss the effects of thinning on tree diameter growth in white cypress forests in New South Wales. They found diameter growth to be sensitive to tree stocking in both early and later age stands and have demonstrated a growth response to thinning over a range of age classes. Horne (1990) was able to demonstrate that spacing of regeneration at an early age produced greater diameter growth and developed a relationship between stand density and age. He showed time to development of ‘merchantable’ sized trees in a stand could be considerably reduced by early heavy thinning. However, he noted stands with very wide spacing developed secondary regeneration and subsequent competition and heavy branching in the lower stem.

Both Lindsay (1967) and Vanclay (1985-4) referred to a dormancy in white cypress through the winter months, Lindsay attributed this to low temperatures. Vanclay (1985-4), in his work on seasonal growth patterns, qualifies the dormancy by growth parameter. He found that there was evidence to suggest height growth displayed a dormancy period through winter, however, diameter growth was much more related to growth factors such as soil moisture. He also found that variation in stem diameter due to moisture status was often greater than annual increment.

Regeneration

White cypress regeneration can be prolific. Being a conifer, it has both male and female cones, i.e. it is monecious. Young male cones and primordia of the female cones form in November / December and develop through to the following spring. Pollen shed follows, usually between August and October which coincides with flowering of the female cones. A peak in pollen shedding and flowering usually occurs in September (Lacy 1972). This is followed by a period of up to 18 months, before seed is mature and ready for release. Mature cones are usually 1-2 cm in diameter, brown, and contain up to 36 seeds, (on average about 20). Seeds are winged, with between 60,000–120,000/ kg.

Seed production is influenced by a number of factors including seasonal variation, edaphic factors and stand density (Lacy 1972). Hawkins (1954 & 66) also found fire to be a factor. Generally, seed production is inversely proportional to stand density. Stands with basal areas greater than 18 m^2 produce very little to no seed (Lacy 1972). The number of seedlings per hectare has also been found to decrease with increasing basal area (Vanclay 1988). Lacy (1972) noted differences in seed production between individuals caused through position in the stand, i.e., dominant or suppressed, and differences between individuals irrespective of stand position, possibly caused by genotypic variation. Good seed crops occur on average one in three years and range between 45 and 60 kg /ha of seed (Hawkins 1954 & 66).

Seed fall occurs in late spring / early summer (October – January) over most of the resource, with some geographic differences (seed fall tends to be later in the north), of the year following fertilisation. A peak in seed fall occurs in November / December. Much of the seed falls within 1 – 2 tree heights of the trunk, however, seed has been recorded up to 400 m distant from the seed source (Hawkins 1966, Lacy 1972). Like other tree species, dispersion distance is affected by tree height, wind speed and topography.

Germination of seed is typically enhanced by a number of factors including bare soil and good soil moisture conditions (Lacy 1972, Johnston 1972), although seed germination has been observed to occur in areas of heavy understorey litter. Establishment and early growth of regeneration is influenced by overstorey, soil moisture and soil cover and type (Lacy 1972, Hawkins 1966, Curtin 1987) as well as both fire and grazing. Johnston (1968) found that while insolation was a major cause of mortality in seedlings, sheep and rabbit grazing were indirectly responsible through removal of ground cover. Dense overstorey often limits regeneration establishment and survival (Vanclay 1988), whereas regeneration is often enhanced following partial removal of overstorey.

Hawkins (1954) found that while better germination occurred in litter under a mixed forest, in part due to the beneficial effects of protection from insolation, lighter textured (sandier) soil types found under most white cypress forest types were generally not limiting. His work identified the most consistent factor influencing regeneration establishment and survival in white cypress was soil moisture.

Regeneration in New South Wales tends to be episodic in nature with two well recorded ‘waves’ of regeneration, in the late 1890s and in the 1950s which now form the majority of the commercial resource on New South Wales State forest, particularly in the Pilliga (Anon 1982). These events corresponded with a period of above average rainfall following a period of drought (1890s) and control of the rabbit plagues with Myxomatosis virus in the 1950s. In contrast, regeneration in Queensland tends to be more regular with an increased incidence of regeneration ‘events’ providing a ‘trickle’ of regeneration through the intervening periods between natural events over and above normal seasonal conditions. This is possibly due to the yearly rainfall distribution where there is a pronounced higher rainfall period through summer months following seed fall. However, regeneration events which produce large amounts of even-aged regeneration also occur in Queensland given particular circumstances such as removal of sheep from grazing leases coinciding with a good seed crop.

Fire

White cypress is known to be sensitive to fire, particularly in the early regeneration stage. Several authors (Lacy 1973, Lindsay 1967, Johnston 1975) list fire frequency as a major contributor to the distribution of white cypress forests. Fire exclusion following reservation of State forest has been a major factor in the development of the Crown white cypress resource.

In relatively pure white cypress forest, the minimal litter fall habit of white cypress and shading out of other understorey species reduces fire hazard substantially and fire will not generally carry in these stands (Lacy 1973) with the exception of severe wildfire. However in mixed forests litter accumulation on the forest floor from eucalypts increases fire hazard substantially and in these forests wildfire is a major factor in the distribution of white cypress (West 1988). Frequent burning often results in loss of white cypress from these stands.

White cypress forests are vulnerable to fire following either silvicultural thinning, harvesting or a natural event such as a major storm when an increased litter load is present. This increased fire danger may last for a number of years depending on fuel loads and litter breakdown.

West (1988) investigated the influence of fire on white cypress management during the 1980s. He found that while prescribed burning was able to reduce the fuel loads and hence reduce fire hazard, it was associated with loss of regeneration and damage to larger trees. Some success was achieved under optimum conditions, however, it was found these were of short duration and difficult to plan for. In mixed stands he concluded that regular burning may remove the white cypress component altogether from the stand while in pure stands regeneration up to 9 m in height will be lost as well as increased tree defect in the lower part of the log.

More recent work (Male, P. *pers comm* 2000) has persisted with prescribed burning in the mixed and lower quality stands and this has met with success with the application of aerial ignition technology. Some mortality, mostly in the smaller size classes, still occurs with these techniques and further refinements of optimum burning conditions are occurring. The aim of this work is to lower fuel loads so that in the event of wildfire, damage is limited and control is achievable. Further work has attempted to use fire to reduce unwanted white cypress regeneration. Very dense regeneration developing under heavily logged stands will compete with the larger trees in the stand and reduce growth rates and thus productivity. Prescribed burning in these densely regenerated stands has proved unsuccessful. Traditionally, fire has also been a preferred method of control for managing invading white cypress regeneration on freehold land (Male 1974).

Area and distribution

Information on the area of white cypress forest has largely been generated by State agencies[2]. These include:

- Queensland – DPI-Forestry, Environmental Protection Agency and Department of Natural Resources
- New South Wales – State Forests and New South Wales Parks and Wildlife Service.

More recently, the National Forest Inventory (NFI) has collated these estimates of area by forest type. However, mapping of these inland areas is still being undertaken and estimates of area by forest type are being updated regularly, particularly for freehold and leasehold tenure.

[2] Information to develop maps and data tables has been supplied by a number of agencies. These include: Qld Department of Primary Industries – Forestry, Qld Department of Natural Resources, Bureau of Resource Sciences, AUSLIG and State Forests of New South Wales.

Essentially, mapping of forest types is undertaken using a combination of satellite imagery, aerial photography interpretation (API) and use of existing inventory data. While remote sensing provides relatively accurate information for forest typing it does not provide information on forest condition and resource. Resource information for white cypress forests is available for State forest and other public lands in both New South Wales and Queensland from a system of inventory plots. However, in recent times this information has proved inadequate in Queensland and is currently being updated in both states (Mannes, D. *pers com* 2001,Bragg, C. *pers com* 2002, Anon (A) & (B) 2000). By comparison, inventory and resource information for forest areas on freehold land is negligible.

Queensland white cypress forest distribution maps and areas were developed using three data sources, one supplied by DNR and two supplied by DPI-F. The DNR coverage was developed using satellite imagery. The accuracy of this data is doubtful and came with a suggestion to use with caution. DPI-F coverage consisted of digitised camp plans and maps produced by systematic ground survey of the forest estate. A further component of the DPI-F coverage, areas around the Tambo region, was developed from API. These three layers were combined to create a single map and areas common to two or more coverages were corrected to record only a single area.

Only the DNR coverage contained information on the dominance of white cypress, and this was limited to the western part of that coverage. The dominant / subdominant attributes for the remainder of the Queensland coverage were determined at a district level in consultation with Forest Officers, research data and knowledge of some forest areas and is approximate only.

New South Wales mapping data was developed using a similar methodology as for Queensland data. On State forest, the data was based largely on permanent yield plots (120 plots / 400,000ha). Using this method, most forests in this area tend to be either pure white cypress stands or mixed eucalypt forests with white cypress. This is somewhat of an artifact of the methodology used as many of the mixed forest types had been silviculturally treated leaving only white cypress dominant forests based on this method. In the absence of other data, pure white cypress stands were mapped as white cypress dominant while the mixed species forest were mapped as white cypress subdominant.

Tables 1 and 2 below provide the available estimates of white cypress forest in New South Wales and Queensland. Table 1 provides estimates of the total area of white cypress forest, including public lands, by dominance class. Dominance refers to the relative composition of the forest in terms of both species mix and structure. Subdominant implies that white cypress is a secondary species both from a species composition and structurally. Table 2 provides area of white cypress by land tenure. Data is presented pictorially in Maps 1 – 7 attached.

Table 1. Area of white cypress forest in Queensland and New South Wales by dominance class.

Dominance	Queensland	New South Wales	
	Area (ha)	Area (ha)	Total (ha)
Sub-dominant	1 156 552	1 768 212	2 924 764
Dominant	826 393	382 770	1 209 163
Total	1 982 945	2 150 982	4 133 927

Table 2. Area of white cypress forest in Queensland and New South Wales by land tenure.

	Queensland	New South Wales	Total
Tenure	Area (ha)	Area (ha)	Area (ha)
Conservation Reserve	9084	60 588	69 672
Forestry Reserve	618 272	285 791	904 063
Other Crown Land (Leases etc)	481 254	1 367 907	1 849 161
Private (Freehold)	874 335	436 480	1 310 815
No Data	0	216	216
Total	1 982 945	2 150 982	4 133 927

Industry and markets

Silvicultural management of commercial white cypress forests

Development of silvicultural management systems for timber production in white cypress forests has been primarily on State forest areas with the aim of optimising sustainable timber production. There has been no major forest management ethic developed on private land in the white cypress zone. In recent times, changing community expectations have resulted in management systems on Crown lands being adapted to deliver ‘multiple use’ outcomes such as habitat, biodiversity conservation and soil and water values. In this, some compromises have been made in regard to timber production, however, the prime aim of most Cypress Pine State forest areas in Queensland and New South Wales remains production of timber. Other land uses, such as grazing and honey production have continued to coexist with these aims. Regional assessments of Crown lands which include the white cypress zone in both States are currently underway and it is likely that some or many Crown forest areas will be reserved for values other than timber production.

Primarily, forest management activities have involved fire protection, establishment of regeneration, thinning and harvesting. Most merchantable white cypress logs are relatively small in comparison to logs from Eucalypt forests, ranging from average stem volumes of less than 0.2 m^3 from regrowth forest thinnings up to and greater than 0.5 m^3 in high quality virgin forests in western Queensland.

Development of specific guidelines for management of private white cypress forests in both Queensland and New South Wales has not occurred with the exception of the guidelines produced by Nicholson (1997), ‘Managing Cypress Pine on Your Property’ which reflect those applied on State forest in New South Wales. Cypress Pine Silvicultural Notes have been compiled for New South Wales (Baur 1988), however, a less holistic approach has been taken in Queensland where harvesting guidelines, thinning prescriptions and other management notes have been compiled separately by DPI Forestry in a ‘Harvesting Marketing and Resource Management Manual’(Anon (D) 2000, Taylor 1997) or in ‘Circulars’.

Management guidelines for Crown white cypress resource in New South Wales and Queensland have been primarily influenced by the growth habit of white cypress, maintaining a supply of timber to milling operations, and in New South Wales particularly, the regeneration habit of large scale episodic events such as in the 1890s and 1950s. More recently economics have influenced management approaches significantly. Essentially, New South Wales and Queensland have developed different approaches to forest management.

In New South Wales a ‘two-tiered’ management approach has been adopted. Horne (1994) describes the system as having two different elements: (i) an overstorey component and (ii) a regeneration component. He recognises five different stages:

- felling current overstorey stage (year 0)
- non-commercial thinning of current regeneration (year 5, regen. 25 – 35 YO)
- commercially thin current regeneration to end crop spacing (year 50)
- establishing regeneration, grow on next overstorey (year 75 – 85)
- fell next overstorey stage (year 100 –110).

Essentially, this is a modified ‘shelterwood’ system which provides for regeneration by retaining sufficient seed trees in the overstorey. Important aspects of this system include the establishment and thinning of regeneration.

Knott (1995) provided a comprehensive summary of trial plots in New South Wales state forest and recommendations on optimal thinning regimes for a range of stand types and ages:

- unthinned stands < 30 years old – thin to approx 500 stems / ha (4.5 x 4.5 m). Response 20 – 30 years post thinning.
- 30 – 60 year old stands with some past management – thin to 6 – 9 m^2 / ha basal area. Expected growth 0.25 – 0.4 m^2 / ha / year. Heavier thinning will increase individual tree DBH increment significantly but reduce overall BA increment.
- 60 – 100 year old stands – thin to approx 5 – 10.5 m^2 / ha (150 – 400 stems / ha). This will typically produce basal area increments of between 0.2 – 0.35 m^2 / ha / year. Again, heavier thinning will improve individual tree diameter increment but reduce BA increment.

In Queensland, management of stands has been described by Johnston and Jennings (1987) and can be described as Selective Harvesting or Single Tree Selection. Management has varied across the resource with more intense management in the eastern resource, held under more secure tenure as State Forest, than that of the western resource which is mostly on leasehold land. In the eastern resource, management has been relatively intense, with a cycle of silvicultural thinning and harvest and up till recently complete fire protection with the exception of wildfires. Thinning regimes incorporate the principle of providing sufficient growing space for selected trees while maintaining full site utilisation, i.e., maximising commercial volume production (Henry 1960). Harvesting aims to remove the accumulated ‘capital’ growth by removal of trees considered to have reached maximum potential, thinning the remaining merchantable component on the basis of tree size to induce a growth response and inducing regeneration and rapid early growth. In some areas of the eastern resource in Queensland there has been up to three cycles of treatment and harvest, while maintaining a continuous forest structure.

In the western resource, management has been more extensive as much of the resource is on land held under grazing lease. There is no policy of fire exclusion and no silvicultural treatment. Up till recently, harvesting has been on a diameter limit basis where trees above a set diameter are harvested. In some stands this has resulted in most of the white cypress component being harvested. Current management is to tree-mark for harvest and promote fire exclusion from logged stands for a period to ensure successful regeneration and a harvest interval in a shorter timeframe.

Private land

There are few instances of past management of white cypress on private land documented. One such case in Queensland has been documented by Greening Australia (Guijt & Race 1998) and outlines a landholder who has successfully practiced selective harvesting and harvest scheduling for approximately 40 years. This lack of private forest management is consistent with anecdotal evidence from agricultural extension staff in both states. It is further evidenced by the falling levels of harvest from private land in both states. In part, this can be attributed to the long term nature of forestry, limited information available for private forest owners in relation to forest management practices and the general value of the forest resource when poorly managed.

Productivity

White cypress is a relatively slow growing species and diameter and Basal Area (BA) [3] increments are low in comparison to other commercial forest tree species in Australia. Diameter increments of between 0.2 – 0.5 cm / annum are consistent across the resource for silviculturally well managed stands (West 1990, Knott 1995), however, much larger increments, 0.8 – 1.0 cm / annum, have been reported in some research trials (West 1989). Basal area increments of between 0.15 and 0.5 m^2 / ha / year are also typical. While higher basal area increments are often associated with higher tree

[3] Basal Area is usually expressed as square metres per hectare and represents the sum of the cross sectional area of trees at 1.3m. It is used for comparison of the relative density of trees.

densities and smaller tree diameters, many researchers have identified an ‘optimum’ BA range and stocking where commercial productivity is maximised (Horne & Robinson 1987, West 1990, Johnston 1975).

Vanclay and Henry (1988) in their paper on site form in cypress pine forests have developed a useful indicator for assessment of site productivity. In their work, site form, the height of a tree 25 cm DBHOB, was correlated to Basal Area increment and hence productivity. In natural forests where tree age is unknown, a ‘site form’ indicator provides a useful method to assess site potential and provides a guide for planning forest management.

Horne and Robinson (1987) investigated response to thinning of older stands of white cypress in the Baradine area. They found an optimum basal area range of between 6 – 8 m^2 / ha with an allowable range of between 6 – 10 m^2 / ha for maximum commercial productivity. This fully utilised the site and thus maximised volume production. Johnston (1975) in his work on thinning studies in southern Queensland concluded that much higher Basal Areas, up to 20 m^2 / ha, could be maintained however recommended a range of between 12 –15 m^2 / ha reducing to 6 m^2 / ha to obtain regeneration. Much of this work was undertaken on areas of high ‘site form’ and areas of lower potential productivity are known to support lesser stocking densities. Vanclay (1985) also found an optimum range for maintenance of basal area, however, he linked this to ‘site form’ and demonstrated that higher site forms were able to maintain higher optimum basal areas.

Horne and Robinson (1987) and Johnston (1975) noted a reduction in diameter increment on some sites on trees with larger diameters. Vanclay (1985-3) however, in his work on growth modelling, found that tree growth was more related to stand basal area and time since thinning treatment than tree size.

Both State forest agencies in New South Wales and Queensland have a comprehensive data set based on growth and yield or experimental plots providing estimates of forest productivity, condition and trend. This is supported by other inventory information based on temporary plots to provide more detailed information for particular State forest areas for planning. Both agencies have developed stand growth models from this data on which to develop sustainable harvesting levels across the State resource.

Little to no information is available for private lands on forest condition and growth rates. Some plots have been established on private land as part of a range of projects but these are relatively few in comparison to the total forest area.

Selected growth rates are given (Table 3) as an example for specific locations. Caution needs to be exercised in extrapolating these figures as the selected plots have been subject to a range of management regimes over time and comparisons should only be made within, and not between, sites.

Table 3. Growth rates of selected plots in Queensland and New South Wales.

Location	Age Class	Stocking Stems/ha	Mean DBH (cm) end of period	Basal Area Increment M^2/ha/annum
NSW				
Back Yamma SF*	1890s regeneration.	93	34.3	0.35
		204	29.2	0.44
		303	26.2	0.43
Merriwindi SF**	1908 regeneration.	148	29.7	0.24
		346	23.3	0.31
		784	18.6	0.32
Qld				
Inglewood SF ***	uneven	357	21.1	0.22
		768	16.1	0.15
Barakula SF***	uneven	526	10.4	0.4
		637	8.9	0.17

*From Horne & Robinson (1986), Diameter Growth of mature Cypress Pine in the Forbes district. O'Neil Plots - High site quality plot.
** From Knott (1995). White Cypress Thinning Trials of the Western Region. Experiment U21204
***From West (1990). Cypress Pine Silvicultural Management. The Future. Expt 307 Wck. and Expt 168 Dby.

Processing industry

Processors

There are approximately 60 white cypress sawmills operating in Queensland (Anon. 1998) and 53 in New South Wales (Anon 1996). Many of these are relatively small sawmills processing a mix of Crown allocation and privately sourced timber. Traditionally, these sawmills were relatively low technology operation, however, for the sawmills supplying the high quality markets, increased quality and consistency of sawn product is required. This has resulted in investment in kiln drying and dry mill processing technology. Some sawmills have invested in this on their own and have endeavoured to increase throughput to develop some economies. Others have formed cooperative arrangements or 'farm out' the dry milling components.

Timber

White cypress timber has a light coloured sapwood with a darker, yellow to brown heartwood. It is not susceptible to lyctus[4] attack and has an air dried density of approximately 680 kg/m^3. It has a distinctive odour and the heartwood is durable in both external and in-ground situations being highly resistant to both termites and decay. Typically, the sawn timber is knotty and somewhat brittle with contrasting colours and grain. It has been commonly used for both structural and framing timber in the past and this remains a large market, however, increasingly feature quality markets are being sought out both domestically and overseas (Swain 1928, Anon 1996).

Green-off-saw recovery (expressed as the percentage of sawn timber in nominal dimensions per original log volume) for white cypress typically ranges from 36% to 45%. Reductions in saleable volume after drying and dressing are generally in the order of 10 to 25%, therefore providing an average dried, dressed recovery figure of 82% (as a proportion of green sawn input volume). Production of wide boards is more profitable to the processor and larger logs generally provide a higher recovery of the desired widths than smaller logs. Narrow boards (75mm or 3 inch) are

[4] Lyctus or powder post borer is a small boring insect which attacks sapwood of some hardwoods. Lyctus susceptible timber has to be treated or removed by law before sale.

problematic for processors in both Queensland and New South Wales with limited markets and negligible profits.

As with other sectors of the timber industry, white cypress processors are investigating environmentally friendly and/or commercial options for residue utilisation. Cypress chip has been found suitable for landscape mulch and, in small proportions, as fibre for reconstituted wood panel products. Bark is enjoying popularity in the landscaping industry where it is marketed as 'cypress red'. Smaller volumes of sawdust are utilised by poultry farms. There is some interest within the industry regarding the potential of essential oil extraction, and energy supplementation by burning residues. White cypress processors currently use either/ or both air-drying and kiln-drying methods to produce seasoned product. Kiln drying is essential for the production of export timber due to the lower moisture content requirements for North American and Japanese destinations. Seasoning technology varies within the industry from the use of dehumidifiers and gas-assisted solar kilns to large-scale conventional kilns.

Timber properties

White cypress is unique among softwood timber species due to its superior durability and density properties. No other commercial softwood (i.e. gymnosperm or cone-bearing plant) rates as high in these important characteristics. Table 4 below lists the major commercial softwood species in comparison to white cypress.

Table 4. Comparative wood properties of softwood timbers.

Trade Name (origin)	Density[1]	Durability[2]	Suitability for feature flooring
White cypress (Aus)	675 kg/m^3	1	Yes, including platform construction
Hoop pine (Aus)	560 kg/m^3	4	Yes, light traffic only e.g. bedrooms
Caribbean pine (Aus)	545 kg/m^3	4	Yes, light traffic only e.g. bedrooms
Douglas fir (NA, NZ)	560 kg/m^3	4	Yes, light traffic only e.g. bedrooms
Western red cedar (NA)	380 kg/m^3	2	No, too soft
Radiata pine (NZ)	490 kg/m3	4	Yes, light traffic only e.g. bedrooms

[1] Density at 12% moisture content, i.e. 'air-dry';
[2] Durability ranking in accordance with the 4 class scale nominated by AS1720-1990 Timber Structures Code. Class 1 = timbers of the highest natural durability; class 4 = timbers of low durability.
Source: Smith W.J *et al.* 1991.

White cypress is classified as a low shrinkage timber with average values from green to air-dry (12% moisture content) of 2.4% radial and 2.6% tangential, and unit shrinkage of 0.22% radial and 0.26% tangential. Comparative shrinkage data of other feature flooring species are presented in Table 5 below.

Table 5. Comparative shrinkage data of feature flooring timbers.

Standard Trade Name	Radial Shrinkage[1]	Tangential Shrinkage	Radial Movement[2]	Tangential Movement
White Cypress	2.4%	2.6%	0.22%	0.26%
Brush Box	4.4%	9.7%	0.34%	0.38%
Spotted Gum	4.3%	6.1%	0.32%	0.38%
Rose Gum	4.0%	7.2%	0.25%	0.34%
Tasmanian Oak	5.2%	8.5%	0.22%	0.35%

[1] Loss in dimension from the 'green condition' to 12 % moisture content;
[2] Percentage change in dimensions with each one percent change in moisture content (below approximately 25% (unit shrinkage).
Source: Kynaston W.T, Eccles D.B. and Hopewell G.P. 1994.

Whereas most timbers are stronger in the seasoned condition compared with the green condition, white cypress has similar stiffness values both green and seasoned and is therefore usually sold green for framing applications. The stress grades achievable when visually graded in accordance with the relevant Australian Standard are F4, F5 and F7.

The timber can be machined and turned to a fine finish, although the knots can be problematic due to chipping out in some material. The sanding dust, as with many commercial timber species, is an irritant to the mucous membranes (Bootle, 1985).

Seasoning is generally a straightforward process with rapid drying rates, negligible distortion and minimal splitting. Some surface checking occurs during the early phase of drying, depending on severity of conditions.

Products - Domestic

- *Minor products* – White cypress is used in a large number of products. This includes cypress furniture, i.e., outdoor settings, bookshelves, coffee tables, entertainment units, bedside cabinets, playground equipment, cubby-houses and dog kennels. Secondary processors have produced edge-glued panels for furniture, however, white cypress is not favoured for this application, due to the critical machining/gluing issues, and problems associated with knots. Laminated bench tops are produced for the domestic market, but White cypress only represents a very small proportion of total bench output.
- *Posts* - Square section posts are being produced by most sawmillers for pergolas and verandahs. White cypress has advantages over competing species such as Douglas fir because of superior durability, and local hardwoods (eg tannin staining, high shrinkage eucalypts). White cypress also enjoys a reputation with homeowners and builders for straightness. The current retail value of 100x100mm posts sold in Brisbane is $\$785/m^3$.
- *Sub-floor framing* - Green bearers and joists are produced by most sawmillers and sold locally and interstate. Most common sizes are 150x75mm (Brisbane retail $\$713/m^3$) and 200x75mm (Brisbane retail $\$767/m^3$) in lengths of 3.6m, 4.8m and 6m (2001).
- *Strip flooring and lining boards* - Tongue and groove flooring is generally supplied in 85mm cover width, 20mm thick, in lengths from 0.9m to 6.0m (ex-mill $\$580/m^3$ to $\$690/m^3$ for standard, $\$50/m^3$ surcharge for end-matching, add 10% for 'polish' grade if specified. Flooring retails from \$1400 to $\$1800/m^3$. The most popular profile available in White cypress flooring is reversible, that is, it can be installed as T&G flooring or if reversed, VJ lining (profile V1F). Strip flooring is seasoned to between 10 and 15% moisture content, with the target moisture content at the lower end of this range for most domestic destinations. Lining boards are also produced in 12mm thickness.
- *External decking* - Decking is usually dressed green and sold in southern markets, with most going into the Melbourne market. Pencil round, shot-edge and reeded profiles are supplied, most commonly in 75mm wide profiles.
- *Cladding* - Chamfer boards (dressed) and weatherboards (rough-sawn) are produced in a range of widths (mostly 100 and 150mm). These products account for a lesser proportion of output than flooring and framing, but demand remains steady from year to year. Typical prices for cladding range from \$580 to $\$620/m^3$ ex-mill.
- *Fascias / bargeboards / roof trusses* - Fascias and bargeboards are supplied at 200x25mm and 200x28mm and retail for $\$1112/m^3$ in Brisbane. Manufactured trusses retain popularity with builders and specifiers in some areas, particularly the Darling Downs of southern Queensland.
- *Fencing timber* - Fence palings, rails and posts are produced, with most product destined for the Melbourne market. Fence palings ('pickets') are generally derived from fall down board material.
- *Laminated beams* - A Victorian timber engineering company has undertaken considerable product development with white cypress laminated beams, and are currently producing a patented beam ('Durabeam') primarily for the domestic market. Laminated White cypress components have been supplied in footbridge kits exported to Japan. Several of the Queensland mills surveyed supply

dry 38mm section material to this manufacturer, who subsequently dresses the timber to 33mm and laminates with an ‘A’-type bond and additive.

Products - Export

The two principal export markets are Japan and the United States, however, other spot sales have occurred into Asian countries and this may develop with time and marketing. Products include:

- *Posts* - Square section posts (108x108mm) are being exported to Japan by several of the companies surveyed. It is expected that this product line will increase in volume, assuming that quality remains consistent and Japanese buyer confidence remains stable.
- *Sub-floor framing* - Square section bearers (Dodai) are currently sold into Japan.
- *Flooring* - Both strip flooring and overlay flooring are produced for export markets, destined for Japan and North America. Seasoning requirements are different for timber products used in the northern hemisphere due to lower equilibrium moisture contents (drier average environments, 6 to 9%). Grade quality specifications are often higher as well. Therefore the higher trade price achieved for export White cypress ($850 to $900/m^3) doesn’t necessarily imply higher profits, as seasoning and grading costs are higher than for domestic flooring.

Sawmilling residue

As with other sectors of the timber industry, White cypress processing companies are investigating environmentally friendly and/or commercial options for residue utilisation. White cypress chip has been found suitable for landscape mulch and as fibre for reconstituted wood panel products. One manufacturer uses White cypress chip in two panel sheets (one at 2% of the total chip volume, and another at 4%). Bark is also utilised in the landscaping industry and smaller volumes of sawdust are utilised by poultry farms. Essential oil extraction is being carried out on a small scale in both States however a firm market remains elusive. Another option being considered is fuel briquettes.

Industry development

- *Energy*- Opportunities are emerging for wood biomass to be used in the production of renewable energy. Through the National Greenhouse Strategy, Australia is committed to reaching a renewable resource energy target of 2% by 2010. CSIRO researchers consider wood residue energy will be cheaper than alternatives such as coal (1kg wood per kilowatt hour =$0.25 per megajoule, coal=$0.27-$0.29 per megajoule), and could reduce Australia’s greenhouse gas emissions by as much as 10%. Tax incentives and other Government schemes may render this option worthy of further investigation by the cypress industry. The technology for wood biomass conversion to electricity or process heat is well developed and can be implemented on almost any scale.
- *Oils*- The major essential oil present in white cypress is derived from citronellic acid, originally described as the phenol ‘callitrol’, a white crystalline solid also known as sandarac. Other constituents warrant further investigation for potential products.
- *Flooring systems*- Overlay and floating floor systems, although well entrenched in northern hemisphere markets, are relatively new concepts for domestic flooring applications, but offer good utilisation of short lengths and narrow boards. Cypress is well suited to the application of pre-finished flooring panels, due to its’ low shrinkage, superior hardness compared to other softwood floor options, and continued market demand for a knotty, feature floor.
- *Extractives*- Research has investigated the feasibility of recycling durable extractives from cypress residues to impregnate the non-durable sapwood. While successful tests were completed, the process was found to be uneconomic and there is currently no interest in further development.

Pests and decay fungi

This section describes and documents the major pests and decay fungi affecting white cypress timber production.

Relatively few pests and decay fungi affect native cypresses. The most consistently damaging insects and diseases are **small cypress jewel beetle, Durabilla white grub, cypress bark weevil** and **yellow dose** and **brown cubicle rot.** In some situations the results of pest and fungi infestation can be severe, causing timber degrade and significant loss of yield, or making the timber unmerchantable. The habits and potential effects of these organisms should be taken into account when considering or planning stand management.

Other pest insects and diseases have been recorded, for example cypress pine sawfly, termites and *Phellinus* sp., a fungus causing heart rot, but they are occasional or minor problems.

Overall, in this study, pest insects and decay fungi were not major causes of timber degrade or loss of yield. Logs at only a few study sites was affected. Damage was identified either in the standing tree, in the log, or during the milling and grading process.

Insect pests

Three species of beetles, **small cypress jewel beetle**, **Durabilla white grub and cypress bark weevil** can be major or minor pests, depending on severity of infestation. Most beetles have a life cycle of several months to several years and generally four 'stages', i.e., egg, larva, pupa and adult. Termites, the longicorn beetle *Oebarina ceresiodes*, cypress pine sawfly and cypress aphid are minor pests.

Small cypress jewel beetle, *Diodoxus erythrurus* (White) (Coleoptera: Buprestidae)

Small cypress jewel beetles have been described as the most damaging of the cypress pests in New South Wales (Hadlington 1951). This is also true for Queensland (Schulz, J., Kapernick, W., Male, P., Gould, K. and DeBaar, M. pers. comm 2001). The beetles are pests of stressed, damaged or unhealthy standing trees and freshly felled logs. They do not infest seasoned timber. As their common name suggests, they infest native cypresses, *Callitris* spp., but they also attack some exotic ornamental pines such as bookleaf pines and golden cypresses.

Description

Adults (Figure 3) are 15 – 20 mm long, with large eyes, short saw-like antennae and a bullet-shaped body which tapers at the hind end. They are brightly and distinctively coloured, mainly dark metallic green with cream to yellowish stripes behind the head and cream to yellowish spots on the elytra (wing covers). The underside is mainly cream, at the hind end there is a patch of dark red with cream spots.

The larvae (Figure 4) are creamy white, elongate and flat. The tiny black head is followed by a wide, almost diamond-shaped segment, the remainder of the body is a much narrower and clearly segmented. Their characteristic shape gives them the common name 'cobras'. Fully-grown larvae are up to 20 mm in length.

Figure 3. Cypress jewel beetle.

Figure 4. Cypress jewel beetle larva and damage on inner bark.

Life history

Adults are present from early spring to autumn. They feed on nectar. Females lay eggs on stressed or damaged standing trees (eg drought stress, storms, logging or fire), or newly felled logs. Eggs are laid at wound sites, in splits and cracks in bark, in broken branch stubs and scars, on freshly cut surfaces, or on the bark of stressed trees. Beetles rarely lay eggs on healthy trees.

Larvae feed and bore in the inner bark and outer sapwood, the feeding area is ‘engraved’ with curved marks made by their mandibles (jaws). Their flattened tunnels are filled with frass (waste material) produced by the larvae, and frass may be pushed out through cracks onto the bark surface and the ground around the tree. The frass is composed of fine dust and soft pellets, although old frass may become compacted, and it often has two colours, brown from the inner bark and very pale from the sapwood (Figure 5).

Figure 5. Typical cypress pine jewel beetle damage on outer sapwood.

Mature larvae cut out a pupation chamber in the inner sapwood or outer heartwood. After pupation new adults chew their way to the surface and emerge through an oval exit hole 4 – 5 mm across, which opens at a slight angle to the timber surface.

The length of the life cycle varies according to conditions. It is generally thought to be about 1 year, but can be much extended in poor conditions. Larvae can continue to feed and grow in drying and seasoned timber. Adults can emerge from the same piece of timber for several years, and have been recorded emerging from timber more than 15-years-old. Hadlington and Gardner (1959) reported two generation per year sometimes occur.

Distribution and hosts

Diadoxus erythrurus is widespread across Australia in the drier inland areas that support *Callitris spp*. (Froggatt, 1923). Small cypress jewel beetles have caused extensive damage to the exotic *Cupressus lambertiana* planted as hedges and windbreaks in coastal and urban areas of Victoria (French 1911). The species spread to the coast and southern highlands of New South Wales after the introduction of *Cupressus* spp. as ornamentals (Hadlington and Gardener 1959).

Damage

Cypress jewel beetles are always present in natural stands of cypress, as adults from spring to autumn and as larvae and pupae all year. They breed in stressed, injured and dying trees, freshly fallen branches, and in stumps and trash after logging.

- Usually minor pests, infesting small injury sites such as fire scars, and wounds from mechanical damage. The wounds eventually heal.
- Become major pests after catastrophic events such as wildfires or severe storms, and if present in large numbers they can kill trees.
- Injury and stress are usually precursors to infestation, for example drought stress, storm, fire or mechanical damage, or the tree is felled.
- Are attracted by chemicals produced by stressed or injured trees, or fresh logs. Eggs are then laid on or in the bark.
- Often external signs of infestation: cracking and lifting bark; frass on the trunk or ground; dying crown in badly infested trees which are close to being ring-barked.

Standing trees

Damage to trees is caused by larvae feeding in the inner bark and outer sapwood. A few larvae cause minimal damage. When there are many larvae they cause extensive damage to the sapwood and the tree can be ringbarked. Effects on standing trees depend on:

- The type of injury to the tree
- The extent of infestation

Minor wounds

Many small wounds that become infested eventually heal, and larval activity stops. Two trees harvested in the current study had old jewel beetle damage which was in the process of healing, no larvae were present. Hadlington and Gardner (1959) found that in trees with small wounds, resin produced around the injury site overwhelmed larvae and prevented spread of larval damage. In winter an absence of adults stops re-infestation of wounds, and pupation of larvae stops feeding damage, this may assist wound healing.

Severe damage caused by wildfires, storms or severe drought stress

- In the months when beetles are active, the trees attract very high numbers of egg-laying females within a few days,
- Egg-laying at multiple sites on individual trees, larvae feed in patches all over the inner bark and sapwood and trees can be ringbarked.
- High numbers of larvae continue to feed in the dead tree, then move into the inner sapwood and heartwood to pupate, damaging the timber.
- About a year later a large population of adults emerges, and can re-infest unhealthy trees. If trees do not die they may be re-infested, and the extensive injuries can be entry points for fungi that cause decay.

Recovery of fire-damaged trees

Hadlington and Gardner (1959) investigated the effects of cypress jewel beetle on damaged *Callitris* after catastrophic fires in Pilliga National Forest in November 1951 and Euglo and Manna State Forests in December 1957. They found that some trees which were infested by cypress jewel beetle larvae, but had some intact and growing crown left, were able to produce resin, and larval activity was stopped. The effect was much stronger after heavy rain. The trees produced resin as beads all over the trunk. Some months after the fires the jewel beetle larvae had disappeared and the trees were growing normally. Trees without growing crowns did not produce resin, even after rain. Larval activity continued, the trees were ring barked and died.

Freshly felled logs

- Cypress jewel beetles are attracted to freshly felled logs within a very short time (hours to days) and begin to lay eggs.
- Logs left on the ground for a long period before processing can become heavily infested.
- Most larvae are destroyed during milling and dressing.

Drying timber

Larvae can continue to develop in drying timber. When logs are heavily infested many larvae will survive in the milled and dressed boards, they will tunnel through, and pupate in, boards being air dried and pallets of seasoned boards. Adult beetles can emerge from cut timber several years old, they have been recorded emerging more than 15 years after harvest, and have chewed through fabric, plasterboard and melamine when emerging. Kiln drying to a core temperature above 65^0 C will kill larvae and pupae.

Implications for management

Cypress jewel beetles are at low levels in stands which are healthy and well managed. Stand improvement measures, such as thinning and controlled burning, will improve tree health. Beetles are not active in late autumn and winter.

Fire / storm damage

- Stand improvement tasks should be carried out in winter if possible.
- Severely damaged trees should be harvested and processed as rapidly as possible after fires or storms in spring and summer. Nothing can be done to prevent or kill off infestations in standing trees.
- Hadlington and Gardner (1959) recorded some recovery of fire-damaged trees after rain. However, it would be a risk leaving severely damaged standing trees that are eventually intended for logging, even when rain was forecast.

- Beetles are not present in late autumn and winter, therefore severely damaged trees could be left for a short period, but they should be removed by late winter - early spring, before the new generation of adults emerges.

Routine logging

- Logging should be carried out with minimum damage to trees which are to be retained.
- After logging the timber should be processed as rapidly as possible. Any developing larvae are usually killed during milling and dressing.
- Kiln drying to a core temperature over 65^{o}C will destroy larvae and pupae in sawn timber.

Historical note

The cypress jewel beetle has long been recognised as a pest of *Callitris* spp. The species was initially described by White in 1846 and again by Saunders in 1868. In the early 1880's extensive stands of white cypress died in the Lachlan district of New South Wales. Dr R. von Lindenfield, a zoologist at the Australian Museum, was commissioned by the Mines Department of New South Wales to visit the area and determine the causes of tree deaths. His report in1885 identified the cypress jewel beetle as the pest responsible. He gave detailed descriptions of the larvae and adults, described their behaviour and included illustrations of adults, larvae and damage.

According to local residents native cypress spread into the area in the 1860's and by the early 1880's was the dominant tree species. The area affected had been suffering drought in the previous years. Dr von Lindenfield's report mentions the impenetrable nature of the pine scrub, and records in one instance a density of 59 'small pine plants' per square foot. It is possible that drought and/or stress caused by overcrowding and competition made the trees susceptible to cypress jewel beetles.
In his introductory paragraphs Dr von Lindenfield noted that large cypresses provide a valuable timber resource, and records the largest on record 'measured 3 feet across the base'. However he considered overall the pine scrub had no intrinsic value and should be cleared for farming and grazing as rapidly as possible. The extent of tree deaths apparently caused by the jewel beetles impressed him so much that he recommended artificial rearing and release of cypress jewel beetles to clear the pine scrub. He calculated that, allowing for natural attrition, one pair of beetles would produce 100,000,000 descendants in 12 years, which collectively would be responsible for clearing one square mile of scrub. Dr von Lindenfield must have been one of the earliest proponents of biological control.

Durabilla white grub

Durabilla white grub (Coleoptera: Cerambycidae) is a native longicorn beetle. The scientific name of Durabilla white grub is uncertain and it is probably an undescribed species. The QDPI insect collection includes two of these beetles collected by Brimblecombe (1956) and labelled '*Tritocosmia latecostata*'. This author has checked the generic and species descriptions, and considers the name to be a misidentification.

The beetle was given its common name Durabilla White Grub (DWG) by Mr Keith Gould, DPI Forestry, because of the extensive damage caused by larvae to standing white cypress in Durabilla State Forest. Very few DWG adults have been found, but from the amount of damage present in logs this beetle may be relatively common in some areas. For many years the damage was attributed to cypress jewel beetles, however this author has reared beetles from a cypress billet, extracted several dead adults from pupation cells in logs and collected larvae from infested trees. A table of differences between the two species is given below (Table 6).

Table 6. Differences between Durabilla white grub damage and jewel beetle damage.

DWG	Cypress Jewel beetle
In apparently healthy trees	Usually needs fire or mechanical damage, or stress to initiate attack.
Larva feeds in inner sapwood	Larva feeds in inner bark and outer sapwood
Larva feeds in trunk and roots	Larva feeds only in trunk
Frass is a fine powder, colour same as sapwood	Frass mixture of fine powder and pellets, colour ranges from same as sapwood to reddish brown of inner bark.
No external signs except for small emergence holes, which heal over. Larvae do not ringbark trees.	Bark can lift and split and peel away. In heavy infestations, trees can be ringbarked
Frass-filled tunnels incorporated into heartwood.	If beetle attack occurs at a wound, and the tree survives, the larval tunnels heal and are not usually incorporated into heartwood. If the tree dies the larvae will tunnel right through the sapwood and into the outer heartwood.

Description

Beetles are very slender and 15 – 20 mm long (Figure 7). The head, prothorax, antennae and legs are reddish brown to dark brown, the elytra are brown, each with three pale, longitudinal ribs. The antennae of the female extend just beyond the mid point of the elytra, the antennae of the male are much longer than the body.

The larvae (Figure 6) are typical longicorn larvae, with a tiny black head followed by a creamy white almost cylindrical body, which is much broader behind the head than at the hind end. The largest larva collected is 38 mm long.

Figure 6. Durabilla white grub larvae.

Figure 7. Durabilla white grub adult.

Life history

Little is known about the life history. The beetle reared from a billet emerged in October, the same month as the adults collected by Brimblecombe. The larva was still active until late July, because it was expelling frass from the billet. This suggests a pupal stage of less than 2 months. The larva cuts a large pupal cell in the sapwood. Larvae collected from trees in May included one very small larva 10 mm long and several larger larvae, up to 25 mm long. It is possible that the life cycle lasts more than one year.

Emerging adults cut an oval hole about 5 mm across (from the emergence hole of the reared insect). Emergence holes have now been found in the trunks of a few trees, and on some logs. They are hard to find in the coarse bark. From samples collected, the hole initially fills with resin and then bark grows across without scarring.

Damage

The damage is caused by the larvae, which feed in the inner sapwood. They move up and down, and spiral around the trunk. This species of longicorn is unusual in that larvae also tunnel in the roots (Figure 8). Most of the larval activity appears to be in the lower part of the trunk and roots, but in severely infested trees the tunnels can extend into the upper trunk.

Larval tunnels are packed with fine, white, powdery frass. The frass-filled-tunnels do not heal or fill with resin, they are gradually incorporated into the heartwood as the tree grows, and in badly affected trees old tunnels are present throughout the heartwood, the pale frass contrasting with the dark heartwood. (*This is different from jewel beetles, which feed in the outer sapwood and bark and in standing trees produce a mixture of white and brown coarse frass*.)

As far as is known DWG does not usually kill the tree. Infested trees (determined on felling) have had healthy crowns. The only external sign of infestation recognised so far is the presence of adult emergence holes on the trunk. However, these appear to heal over, so they are not a permanent feature. In this study all sites had evidence of DWG attack, but only a few tunnels and usually in the bottom 1m of the trunk.

Figure 8. Durabilla white grub tunnels in white cypress roots

Severe DWG infestations

Evidence from QDPI Forestry records, forestry staff and sawmillers shows that in some geographic areas a proportion of trees is severely infested and extensively damaged, with tunnels extending several meters up the trunk and through to the centre, rendering the timber useless (Figure 9). Durabilla State forest is one such area.

Figure 9. Severe DWG damage in cypress heartwood (white patches).

Froggatt (1927) described damage in native cypresses harvested at Forbes, New South Wales, which is remarkably similar to DWG damage. He disagreed with the local diagnosis of jewel beetle damage. He thought it was either another species of jewel beetle or a longicorn.

Distribution

DWG has been recorded in Western Queensland and northern New South Wales with the host. Further investigation may identify a wider distribution.

Factors affecting Durabilla white grub populations

Evidence of Durabilla white grub (DWG) activity was found in 7 of the 9, sites investigated in this study. At the 7 affected sites the activity was limited to one or a few holes in a few trees, and in most of the affected trees the damage was restricted to the butt and did not warrant butting out.

Durabilla white grub in southern Queensland cypress

As previously noted, certain areas of the southern Queensland cypress belt, principally around Durabilla State forest, have extremely heavy infestations of DWG. In affected areas, apparently healthy trees, on felling, may have been so badly damaged by DWG that a large proportion of the log is butted out, or the timber may be rejected at the mill as not merchantable. In extreme cases tunnels extend several meters up the trunk, and from the sapwood to the centre of the tree.

Areas prone to this level of infestation are mainly centred around Durabilla, hence the insect's common name. Outside Durabilla State forest small areas of heavy infestation are reported, but appear to occur in clumps where a few hundred trees are affected, with surrounding cypresses free of DWG.

Identifying factors

It has been suggested that DWG may:

- Be most active on 'hard sites', i.e., ridges with shallow soil and stone or clay, associated with narrow leaf red iron bark, with a low site index, eg, 11 – 13m
- Preferentially lay eggs in suppressed or unhealthy trees, rather than dominant or co-dominant trees
- Be associated with particular plant communities growing with white cypress.

Implications for private growers and state forest agencies

For forest managers with DWG in Cypress stands, knowledge of the level of damage will be critical for any proposed sale. Logs which do not conform to the current industry standard will be rejected and thus investment in forest management such as thinning may be lost. Therefore, consideration should be given to avoiding management inputs into areas with severe DWG damage as it is likely to be uneconomic. Growers must first establish whether DWG is present, then determine the level of damage. At present this can only be done by destructively sampling cypress stands (felling), and by checking old stumps from previous harvests for the characteristic tunnels.

Suggested sample

To ascertain the presence of DWG and determine likely infestation levels the following guidelines are suggested. Fell 30 trees at standard felling height, 22 cm, in a range of sizes, suppressed and co-dominant. For each tree record the number of grub holes and diameter of the stump.

The current adopted commercial standard is:

- 1 grub hole for each 2 cm of diameter, e.g., 10 grub holes in a tree 20 cm in diameter.
- More than 1 hole per 2 cm (exceeds the standard), butt out l m and recount

Where the count exceeds the given standard, management should not be undertaken and further sampling should be done to determine the boundary of the infestation. Usually this is not large, i.e., a small infestation may be less than one hectare. Where grub holes exceed the standard, a minimum commercial log length should be butted as this timber is still suitable for structural purposes and is therefore saleable, although lower returns could be expected.

Cypress bark weevil

The cypress bark weevil, *Aesiotes leucurus* Pascoe (Coleoptera: Curculionidae) is a native species found on *Callitris* spp. The weevils only infest standing trees; unlike jewel beetles they do not lay eggs on freshly felled logs. The damage to the tree is caused by the larva and is commonly called 'Cockie Bite', although cockatoos are not always involved. This weevil has also adapted to, and can severely damage, some exotic cypresses.

Figures 10 and 11. Cypress bark weevil larvae and adult.

Description

The adult is a stout beetle up to 16mm long. It is mainly brown to very dark brown, with a large creamy white patch on the end of the abdomen, and white knees. The integument ('skin') is heavily sculptured (Figure 11). The larva can grow to 20mm in length. It has a well-developed dark head and a curved creamy white body. It does not have legs (Figure 10).

Life history

Eggs are laid in bark. Newly hatched larvae bore through the bark to the outer sapwood. The larvae tunnel and feed in the phloem in the trunk and branches. They leave tunnels packed with powdery frass. When fully grown, each larva chews out a shallow, oval pupation chamber in the sapwood (Figures 12 and 13), and pupates in a 'cocoon' constructed from long shreds of sapwood. In native cypresses this cocoon is characteristic of cypress bark weevil damage. There are always shreds of wood present following pupation, and the shreds often remain under the bark as the wound heals. The emerging adult chews a slightly oval hole about 4mm across, to the surface, through the bark directly over the cocoon.

The length of the life cycle is uncertain. Brimblecombe (1945, 1956) reported that in the closely related Pine weevil *Aesiotes notabilis* the larval stage lasts several months, pupation takes about three weeks and adults can live up to 18 months, an unusually long time for the adult of a timber insect. The cypress bark weevil is very similar to *Aesiotes notabilis* in appearance and behaviour, it would be reasonable to suppose that its life cycle is also similar.

Figures 12 & 13. Cypress bark weevil pupal chamber

Effects on white cypress

When a single larva or a very few larvae are feeding in separate locations on the same tree, the long-term damage is minimal. There is usually some splitting and lifting of bark over the feeding and pupation sites. However, after the adult has emerged the damaged area fills with resin, bark gradually closes across the wound and damage heals without affecting the wood (Figures 14 & 15).

Figures 14 and 15. Old cockybite scar with bark removed over the feeding area (14), resin removed with remains of the pupal cell at the top (15).

Multiple larvae and/or recurring infestations

When there are multiple attacks at several locations on the tree, and/or recurring infestations over several seasons, the damage does not heal. The callus closing over exposed heartwood is again damaged, and there is scarring. Scarring may extend almost round the circumference of the tree, or multiple infestations can result in ringbarking. Exposed, repeatedly damaged sapwood that contains a lot of fine frass may be subject to decay, particularly in wet periods when the frass holds moisture. The decay can spread into the heartwood. This type of infestation can result in timber degrade and loss of yield.

Cockatoos

Cockatoos add an extra layer of damage. Cockatoos can detect weevil larvae and pupae weevils in the trees. They tear at the bark and wood to get at the larvae and pupae (Schultz, J., Kapernik, W. pers. comm. 2001). This causes severe wounds on the tree, leaving bare patches of damaged sapwood which can then become infested with jewel beetles and possibly decay. The result is extensive scarring.

Distribution and activity

Queensland

The populations of cypress bark weevils, and the extent of the damage caused, differ from site to site in Queensland. At the six sites sampled in Queensland in this study, weevil activity was at low levels, and was not directly responsible for loss of yield. In other areas multiple infestations are common and damage is severe (DeBaar, M., Schulz, J., Ince, M. & Kapernik, W. *pers comm*. 2001). There is some evidence to suggest (Brimblecombe 1956, DeBaar, M., Schulz, J. pers. comm., 2001) that cypress bark weevils are more active in poorer quality stands, in trees stressed by overcrowding, drought or other site factors.

New South Wales

Cypress bark weevils are regarded as rare on native cypresses in New South Wales. There was no evidence of weevil activity at the three sites sampled.

Exotic pines and cypresses

Cypress bark weevils were considered rare insects in New South Wales, until heavy infestations of weevils killed ornamental *Pinus halepensis* in Sydney, and eventually stopped this species being used as a windbreak tree (French, 1911). The weevils have also been recorded from other exotics including *Cupressus, Chamaecyparis* and *Cupressocyparis leylandii*. The author inspected a large ornamental stand of *C. leylandi* where most of the trees were ringbarked by these weevils. The trees had been stressed by minor flooding.

Oebarina ceresiodes Pascoe (No common name) (Coleoptera: Cerambycidae)

This small longicorn is a minor pest found in stressed and damaged native cypress. It is most commonly found in fire damaged trees, often together with cypress jewel beetle, but in much lower numbers.

Description

Adults are small, slightly flattened beetles 12 – 15mm long. They are brown, with darker legs and antennae. Larvae are up to 19 mm long, with a tiny black head followed by a creamy white almost cylindrical body, which is much broader behind the head than at the hind end. Larvae feed in sapwood and pupate in the sapwood or outer heartwood. Adults cut emergence holes about 3mm in diameter. Adults can emerge from drying timber and seasoned timber in the same way as cypress jewel beetle, and will not re-infest seasoned timber.

Termites (Isoptera)

Figure 16. Termite activity in a recently felled white cypress stump

Australian Standard 3660.1, 1995, ‘Protection of buildings from subterranean termites’, lists white cypress as being resistant to termite (Isoptera) activity. However termites occasionally infest *Callitris glaucophylla* (Figure 16). The following species have been recorded from white cypress timber, and samples are housed in the QFRI insect collection:

Drywood termites:

- *Cryptotermes papulosus*
- *Cryptotermes primus* (Hill)
- *Cryptotermes gearyi*
- *Cryptotermes queenslandi* (Kalotermitidae)

Dampwood termites:

- *Glyptotermes brevicornis*
- *Neotermes insularis* (Walker) (Kalotermitidae)

Subterranean termites:

- *Heterotermes ferox* (Froggatt) (Rhinotermitidae)
- *Schedorhinotermes intermedius*
- *Schedorhinotermes actuosus*
- *Microceratermes* spp.
- *Coptotermes acinaciformis* complex

Drywood and dampwood termites form colonies of a few hundred individuals feeding in decaying or dead timber. The termites excavate cavities and tunnels within the timber, and do not forage far from the colony. The frass produced is in the form of discrete pellets, and collects in the cavities and tunnels. Dampwood termites, as their name suggests, prefer damp wood and produce moist frass pellets. Drywood termites can survive in damp or perfectly dry seasoned timber, and produce hard, dry frass pellets similar to poppy seeds. Both types are found in living trees, stumps and dead timber.

Subterranean termites form very large colonies (in some species more than a million individuals). They need some contact with soil to obtain moisture, or another source of moisture other than that in the wood on which they are feeding (unlike drywood and dampwood termites). Their nests can be inside living trees, in logs, underground, or some species build mounds or mud nests on trees. Their frass is in the form of soft pellets, and the frass is used in the construction of the nest and galleries, their workings include loose frass. Subterranean termites construct galleries to move across exposed surfaces such as tree trunks. Some species will forage more than 50 m from the main colony.

This study

Drywood termites

Drywood termites were only collected from one site. A colony was found in a single log at the Yearinen State Forest site (New South Wales). The species was identified as *Cryptotermes papulosus* (King 2001), and is a new record for New South Wales, *C. papulosus* was previously only known from South Australia. The colony extended just over 1 m in the centre of a standing tree. The host tree had extensive internal decay, but showed no external signs of damage. An unidentified species of drywood termite has been previously reported from native cypresses in this area (R. Eldridge, pers. comm.).

Subterranean termites

Subterranean termites were present at all sites sampled, but were mainly associated with hardwood trees, hardwood stumps and debris. A small amount of subterranean termite damage to standing white cypress was found at all sites sampled. The termite activity was usually in association with decay and/or scarring. Termites gain access to standing trees mainly through injuries, broken branch stubs, scars or decaying roots. Statistical analysis showed a significant relationship between the presence of decay and the presence of termites. At two sites termites were collected from decaying cypress logs on the ground.

Dampwood termites

Dampwood termites were not found in the study.

Summary

Although some termite activity is associated with white cypress and there may be significant damage to individual trees, the termite activity is usually associated with injury and decay, and termites are secondary pests.

Cypress pine sawfly

Cypress Pine sawfly, *Zenarge turneri* Rohwer (Hymenoptera: Argidae), has been recorded as a pest in New South Wales. The larvae feed on the branchlets of *Callitris* spp.. At times damage has been so severe as to require insecticide treatment (Agricultural Gazette of New South Wales, Nov 1950, Misc publication 3397). There are no recent reports of damage. This insect was not seen at the New South Wales sites during this project. The cypress pine sawfly has not been recorded from Queensland.

Cypress pine aphid

Heavy infestations of Cypress pine aphids, *Cinara tujifilina* (del Guercio) (Hemiptera: Aphididae), were reported to have caused severe yellowing, needle loss and dieback of native cypresses at Baradine (Hadlington and Gardner 1956 citing an unpublished Forestry Commission report). Some trees subsequently died and on inspection were found to be infested with cypress jewel beetles. The severe stress caused by the aphids, and by continuing wet conditions, is thought to have made the trees susceptible to cypress jewel beetles. Cypress pine aphids were not found during this study.

Other insects

A number of other foliage dwelling insects were found, including mealy bugs and some gall formers. All were in low numbers and did not affect the health of the trees.

Decay in white cypress

Gloeophyllum spp.

The major decay-causing fungus in white cypress is *Gloeophyllum* spp., (Simpson and Eldridge 1986). This fungus belongs to the group called the brown rots (Figures 17 and 18). Brown rot breaks down the cellulose in woody tissues more quickly than the lignin. In the early stages of *Gloeophyllum* infection in white cypress the affected tissues are yellowish, appear fibrous and are softer than the surrounding, uninfected wood, the condition is known as yellow dose. As the disease progresses infected tissues shrink, darken and crumble into small fragments, at this stage it is called brown cubical rot.

Figures 17 and 18. Cypress log and stump showing patch of decay (pale crescent) under healing scar.

Infection

Infection is by means of spores produced by the fungal fruiting bodies. The most common route for fungal infection is through wounds, these include broken branch stubs, dead or damaged roots, mechanical or fire scars and insect damage (Simpson and Eldridge 1986).

At a timber mill 100 logs with scarring at the butt end were inspected, and the incidence of decay associated with the scars was recorded. Sixty nine (69) logs had decay associated with the scar.

After fire or mechanical injury in which the bark and sapwood are damaged:

- The bark over the damaged sapwood splits and peels away; there may also be insect infestation.
- The damaged sapwood breaks down and exposes the heartwood beneath.
- The exposed heartwood surface dries and develops fine cracks.
- At the same time a callus forms at the margins of the wound, and sapwood and bark begin to grow across the wound (Fig. 31) eventually healing over.
- In some wounds small pockets of fungal infection and decay develop in the damaged sapwood and/or exposed heartwood. When the callus tissues grow across the wound the decay pockets are enclosed.
- Eventually the wound heals over completely, and the decay pockets are sealed inside the trunk, where the fungus will continue to develop (Figure 17).

In this study several trees that appeared sound and without any signs of external damage, were found on felling to have extensive internal decay (Figure 19). The decay probably started at an injury site and spread into the heart.

Figure 19. Brown rot (*Gloeophyllum* spp.) in a board sawn from a log harvested at site 7 of the study.

Phellinus spp.

Figure 20. Fungal fruiting body at the base of a white cypress, site 4 Baradine.

At Baradine, a white cypress at site 4 (not one of the sample trees) had large fruiting bodies at the base (Figure 20). The fruiting bodies were identified as *Phellinus* spp., a fungus which causes heart rot. The tree was felled and extensive heart rot was revealed.

Sawing study

Methodology

This component of the project was based on the hypothesis that white cypress forests that have been subject to past silvicultural forest management (selection & spacing) will provide a higher proportion of better quality logs with less defect and more feature quality recovery than forests which have not been subject to past silvicultural management. This hypothesis was put forward by cypress sawmillers (Gersikowski, V. & Holland, T., 1999 pers. comm.) who harvest trees from the more intensely managed Crown forest estate areas in eastern Queensland where they have evidenced increasing quality of timber over time in their processing operations. This is particularly relevant to current and expected markets where the emphasis, and profit margin, is on recovery of feature quality timber for high value export markets.

To investigate this hypothesis required that selected, comparable trees with different management histories be sawn and recovery compared. On the basis of the white cypress forest distribution maps developed (attached Maps 1 – 7)) and anecdotal knowledge of the productive resource from SF New South Wales and QDPI Forestry, three localities were selected for sampling on a transect running from north to south through the middle of the New South Wales and Queensland resource, i.e., near Chinchilla in the north to near Baradine in central New South Wales. The three localities selected on this transect sample the major part of the managed resource in both states. Localities selected include:

- Northern locality – This was based on a large area of cypress resource around Chinchilla - Miles. Two sample sites were selected on freehold land near Miles and one to the north of Chinchilla in Barakula State forest.
- Mid Locality - This was based on white cypress areas around the border region of New South Wales and Queensland and the area selected was to the west of Goondiwindi. Two sample sites were located on leasehold land and one on State forest.
- Southern Locality – This was based on three sites in the southern end of the Pilliga State Forest near Baradine. Despite extensive searching near Tamworth and Gunnedah, comparable sites were unavailable on private land and three sites for sampling were selected on State forest.

Sampling site selection within each locality was based on:

- Presence of dominant or co-dominant white cypress forest with comparable site attributes, i.e., soils, topography, vegetation etc
- Past management history – Three management histories were sought; (i) a managed stand including one or more past thinning and harvesting operations, (ii) a partially managed stand with some previous management, generally a selective harvest or thinning, and, (iii) an unmanaged stand with no previous management (either a virgin stand or previous *ad hoc* harvesting).
- Site Form – A measure for comparison of sites based on height in metres of a 25 cm DBH white cypress (Vanclay & Henry 1988).
- Willingness of the landowners to allow harvesting on the sites.

Once sites were selected, detailed site and stand assessments were made to ensure relatively comparable sites within each locality. Given that past forest management is a major influence on standing forest structure and composition, indicators such as soil type and depth, presence / absence of similar understorey species and site form were used for comparison between sites. Following that, detailed stand assessments were made to assist with tree selection for sample harvest. Site descriptions and stand details for each of the nine sites are included in Appendix 1.

Trees for harvest were selected from each stand proportionally to ensure that a numerically representative sample of each diameter group within the stand was harvested. Trees were selected from within the ‘commercial’ range normally used in Queensland of 19 cm DBH +. New South Wales has a lower diameter limit for commercial harvesting (17 cm DBH), however, as two sites were based in Queensland it was decided to adopt Queensland practice for the purposes of this project. Four diameter classes were selected in which proportional numbers of trees were to be harvested, viz,

- 19.0 – 25.9 cm DBH
- 26.0 – 32.9 cm DBH
- 33.0 – 38.9 cm DBH
- 39 cm DBH +

Thirty trees were then selected for harvest based on proportional representation of the commercial sized trees in the stand within each of the four diameter classes, i.e., if 30% of the 19 cm DBH + trees in the stand were in the 19 – 25.9 cm diameter class, 9 trees (30%) were harvested from this size class.

Adoption of a proportional tree sampling strategy is based on:

- Past stand management is primarily responsible for the size class distribution within a stand, so a sampling strategy comparing past management effects should reflect the results of the past management, for example, a higher proportion of larger trees within the stand in a managed forest, and
- To sample trees within a set diameter class would have required a much larger area and thus potentially more variation.

Following selection, trees were measured for diameter and height. They were also examined for the presence / absence of pests, decay fungi or defect. Trees were examined when standing, (using binoculars as necessary), and again after felling, when decay pockets and internal insect damage were visible. The presence/absence of pests, disease or defect, and the amount butted out were recorded. The following characteristics were recorded:

- Gross condition of the crown, biotic and abiotic damage to the crown.
- Condition of the trunk

Particularly, the presence of; (i) scars, broken branch stubs, other injuries eg lightning strike, damage by cypress bark weevil, Durabilla white grub, cypress jewel beetle, termites, (ii) decay -yellow dose and brown cubical rot, other decay fungi, and, (iii) white line, otherwise called sap crack.

Following felling, trees were numbered sequentially (starting at site 1), measurements taken, and transported to the sawmill. Some delays were experienced at Baradine due to wet weather however this was within normal timeframe for harvesting timber commercially and no detrimental effects on timber recoveries or graded quality were evident.

Processing

All log processing was undertaken at Gersikowski & Son Pty Ltd in Cecil Plains, southern Queensland due to the intended processing sawmill in New South Wales being destroyed in a fire. Sawing at one mill was an advantage in that processing was consistent between sites and thus differences between sites were more likely to be associated with the log attributes.

Before logs entered the green chain, tree and log identification were checked for legibility. Log number 90 from the Bidgood property was inadvertently processed prior to the sawmilling study, reducing the population from that site to 29 stems. Logs were sawn to produce 25mm boards in standard sizes ranging from 75mm to 150mm in width. Boards were tagged as they came off the breakdown saw by stapling a sequentially numbered tag on the end of each board. This tag number was recorded against the board details (tree number, log number, board number and dimensions).

The logs were broken down into flitches and cants on a Gibson three-knee pony carriage through a circular saw with a 7mm kerf. Edging and resawing were conducted across a Tess one-man bench with a 6mm kerf. All obvious defects were docked out at the Tess outfeed and boards stacked according to width. Where boards could not produce a minimum 300mm saleable length they were diverted to a chipper. All recoverable boards were tallied and green-off-saw (GOS) recovery for each individual tree and site were calculated. The three-inch stock (75mm) was block stacked and set down in a stockpile area. The remaining boards (100mm, 125mm, and 150mm widths) were stripped out and seasoned (kiln dried) in accordance with North American market specifications, which requires the moisture content range to be within 6-8%. Seasoning duration was typically 14 to 17 days. The identities of a number of boards were lost when board ends were docked during stack construction prior to seasoning.

The 75mm boards were dressed green to a dressed-all-round (DAR) profile. The wider boards were dressed to a T&G flooring profile. All timber was graded and tallied in accordance with Gersekowski's in-house specifications. Dried-graded-recovery (DGR) was calculated for each tree and site. Due to the highly featured nature of white cypress, visual grading is somewhat different to the grading of hardwoods for appearance products. When grading hardwood it is usual practice to allocate a grade based on one prominent, limiting defect. In the case of white cypress, where multiple defects are present they are often considered of equal ranking. For the purpose of this study, the reason/s for out-grading were recorded on an equal ranking basis.

Statistical analysis

Prior to analysis, tree 168 (mid New South Wales, managed) and tree 212 (south west Queensland, partially managed) were removed due to green off saw (GOS) values equalling or exceeding dried graded recovery (DGR) values.

Linear regression analysis was used to assess the effect of management on GOS and DGR volumes. Linear relationships between DBH and GOS / DGR volumes were fitted for all combinations of management history and location (eastern Queensland, mid New South Wales, south west Queensland). The slopes of the relationships within each location were compared to determine whether the rate of change in GOS and DGR volumes relative to DBH or stem volume differed significantly at the 5% level among the three management histories. No analysis was carried out on DBH vs log volume relationships. These were plotted from the data and lines of best-fit plotted.

The slopes of the relationships are compared since each site contains a different size distribution of trees and larger trees generally produce larger GOS/DGR volumes. In situations where slopes were not significantly different (i.e. parallel), differences between slope intercepts with the y-axis were compared. Parallel slopes with significantly different intercepts indicate that an increase in stem DBH/volume results in the same increase of GOS/DGR volume regardless of management history, although a similar size tree will produce a greater proportion of GOS/DGR volume at one site than at the other. The term 'rate of increase' in the results represents the steepness of the slopes. The adjusted R2 (Adj. R2) quoted in the results represents the proportion of total variation that is explained by the linear regression.

Results

Timber harvest and log volumes

Tree numbers harvested within each diameter class from each site are shown in Table 7. These are based on proportional diameter distribution within each of the diameter classes from each stand. Log volume was calculated based on the data obtained at the time of harvest using Huber's formula (volume = length x sectional area at midpoint of the log).

Table 7. Tree numbers harvested on each site by diameter class.

Site	Diameter Class (cm DBH)			
	19 – 25.9	26 – 32.9	33 – 38.9	39 +
1	18	9	2	1
2	24	6	0	0
3	22	8	0	0
4	18	11	1	0
5	24	6	0	0
6	21	6	2	1
7	16	13	1	0
8	3	11	13	3
9	25	4	1	0

Average log volumes, minimum and maximum log volumes harvested from each site are shown in Table 8. Data for all trees is presented in Appendix 2.

Table 8. Harvested log volumes for all sites (m^3).

Site / Log Numbers	Total Stem Volume	Average Stem Volume	Min. Stem Volume	Max. Stem Volume
Site 1 (1 – 30)	9.51	0.32	0.1	0.93
Site 2 (31 – 60)	6.41	0.21	0.11	0.36
Site 3 (61 – 90)	4.33	0.14	0.07	0.30
Site 4 (91 – 120)	5.99	0.20	0.10	0.52
Site 5 (121 – 150)	6.23	0.21	0.11	0.4
Site 6 (151 – 180)	6.40	0.21	0.08	0.74
Site 7 (181 – 210)	7.26	0.24	0.12	0.57
Site 8 (211 – 240)	15.19	0.52	0.11	1.28
Site 9 (241 – 270)	5.51	0.18	0.08	0.61

Log volume

In eastern Queensland, an increase in DBH was found to produce a greater increase in stem volume on the managed and partially managed sites over that on the unmanaged sites. This contrasts with both New South Wales and south west Queensland where no differences were found in the relationship between DBH and stem volume for management types. At both localities, a number of logs were very heavily butted and these were excluded from analysis. Results are shown in Figures 21 - 23.

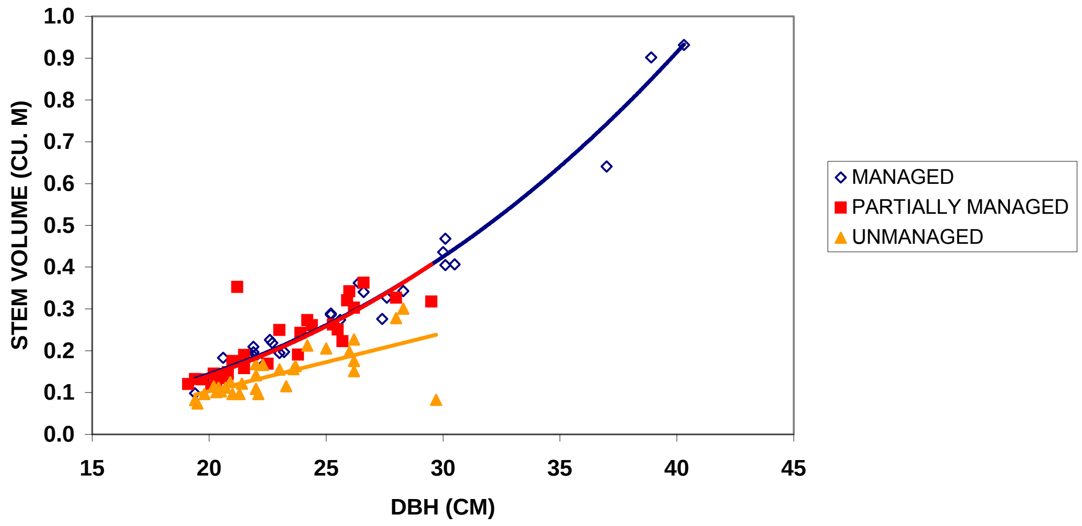


Figure 21. Relationship between DBH (cm) and stem volume (m^3) at managed, partially managed and unmanaged sites in eastern Queensland (Power regression).

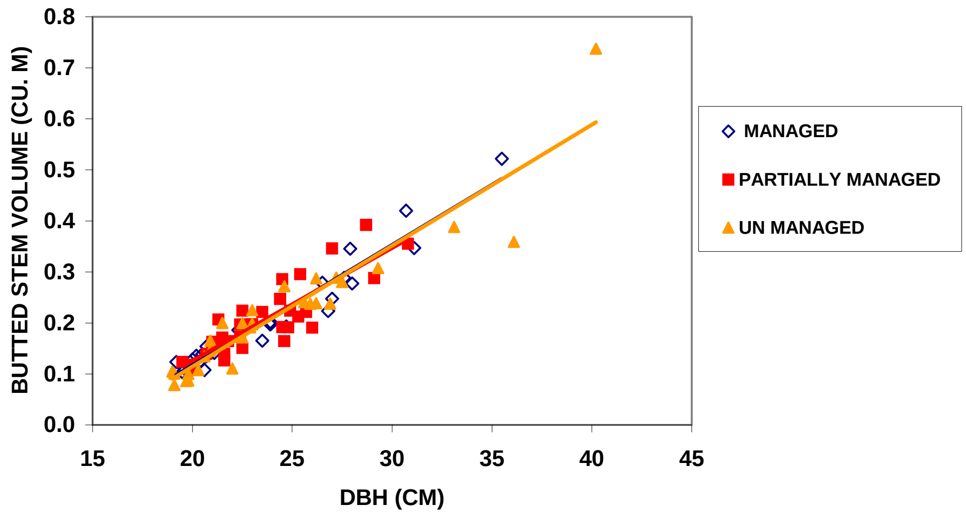


Figure 22. Relationship between DBH (cm) and stem volume (m^3) at managed (wide-spaced), partially managed (close-spaced) and unmanaged sites in New South Wales after excluding trees 93, 107 and 111.

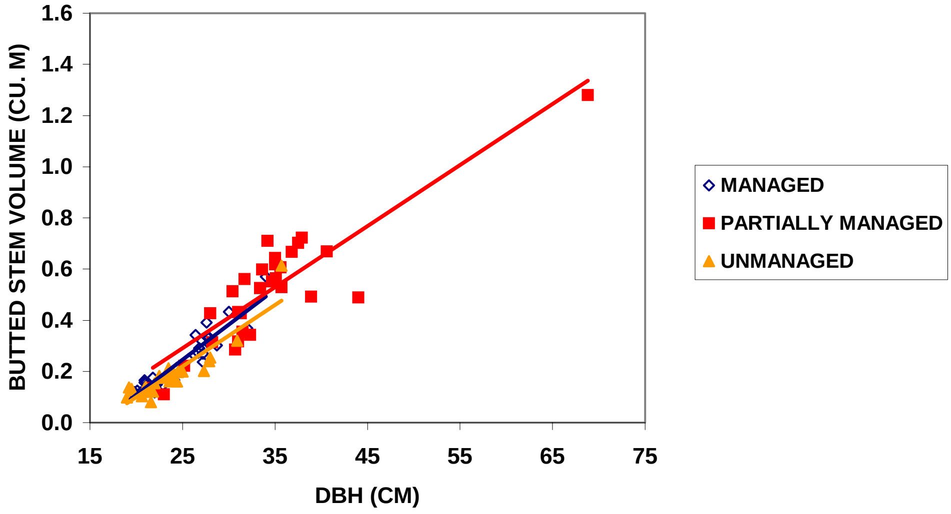


Figure 23. Relationship between DBH (cm) and butted stem volume (m^3) at well managed, partially managed and unmanaged sites in south west Queensland.

Green-off-saw volume recovery

Sawn recovery

Average sawn recoveries for each site are shown in Table 9.

Table 9. Total stem volume, total green-off–saw volumes (GOS) and graded recovery (GR) as a proportion of total harvested volume for all sites.

Site / Log Numbers	Total Stem Volume (m^3)	Total GOS Volume (m^3)	GOS Recovery (%)	Dried Graded Volume (m^3)	Graded Recovery %(of total vol)	GR / GOS %
Site 1 (1 – 30)	9.5	3.9	41	2.75	28.9	70.5
Site 2 (31 – 60)	6.4	2.2	34.3	1.19	18.5	54.1
Site 3 (61 – 90)	4.3	1.3	30.2	0.65	15.1	50.0
Site 4 (91 – 120)	6.0	2.5	41.6	1.74	29.0	69.6
Site 5 (121 – 150)	6.2	2.6	41.9	1.88	30.1	72.3
Site 6 (151 – 180)	6.4	2.2	34.3	1.41	22.0	1.56
Site 7 (181 – 210)	7.3	2.9	39.7	2.12	29.2	73.1
Site 8 (211 – 240)	15.2	6.12	40.2	4.45	29.3	72.7
Site 9 (241 – 270)	5.5	2.2	40.0	1.51	27.4	68.6

In eastern Queensland, management history had a significant effect on the relationship between DBH and GOS volume ($F_{2,83} = 39.0$, $P < 0.001$; Adj. $R^2 = 0.91$). An increase in tree diameter led to a significantly greater increase in GOS volume in the managed forest than in the partially managed or unmanaged forests (managed vs. partially managed: $t_{0.05,83} = 5.3$, $P < 0.001$; managed vs. unmanaged: $t_{0.05,83} = 8.0$, $P < 0.001$). Similarly, the rate of increase in GOS volume relative to DBH was significantly greater in partially managed forests than in the unmanaged forest (partially managed vs. unmanaged: $t_{0.05,83} = 2.3$, $P = 0.024$).

This contrasted with New South Wales where there was no significant effect of management on the rate of increase in GOS volume relative to DBH ($F_{2,83} = 2.2$, $P = 0.119$). However, the effects of management were significant after excluding trees 93, 107 and 111 (site 4, managed), which had large volumes removed by butting defect at harvest ($F_{2,80} = 17.9$, $P < 0.001$; Adj. $R^2 = 0.83$). The rate of increase in GOS volume was significantly smaller at the unmanaged site than at the managed and partially managed sites (managed vs. unmanaged: $t_{0.05,80} = 5.7$, $P < 0.001$; managed vs. unmanaged: $t_{0.05,80} = 3.4$, $P = 0.001$), but did not differ between the managed and partially managed sites ($t_{0.05,80} = 1.0$, $P = 0.321$).

In south west Queensland, there was no significant effect of management on the rate of increase in GOS volume relative to DBH ($F_{2,83} = 2.5$, $P = 0.090$). Although the p value indicates a weak tendency towards a greater rate of increase in GOS volume at the partially managed site than at the unmanaged site, one large diameter tree strongly influences the estimate of the slope at the partially managed site, so interpretations about any differences should be made cautiously.

Data are shown in Figures 24, 25 and 26.

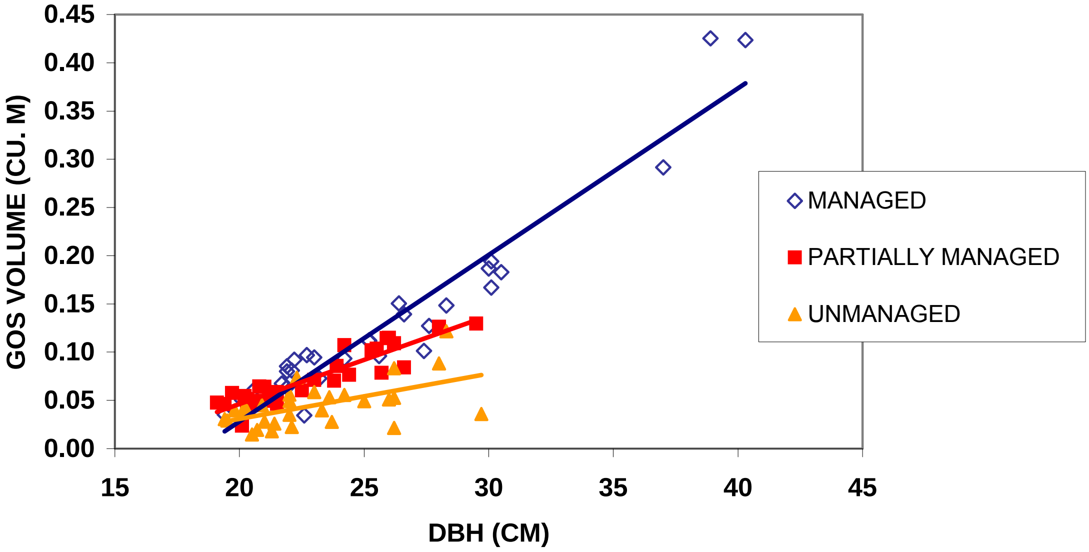


Figure 24. Relationship between DBH (cm) and GOS volume (m^3) at managed, partially managed and unmanaged sites in eastern Queensland.

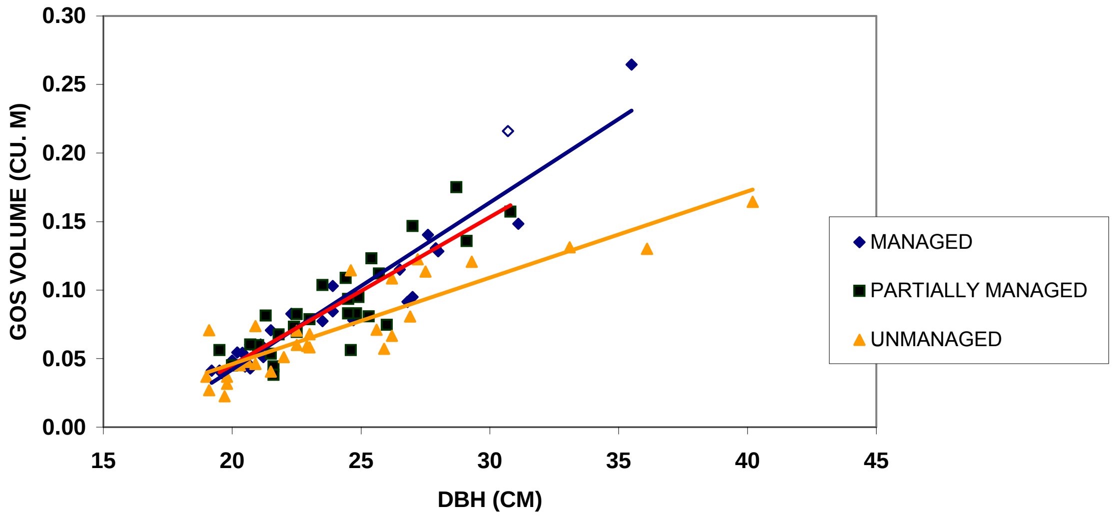


Figure 25. Relationship between DBH (cm) and GOS volume (m^3) at managed, partially managed and unmanaged sites in New South Wales.

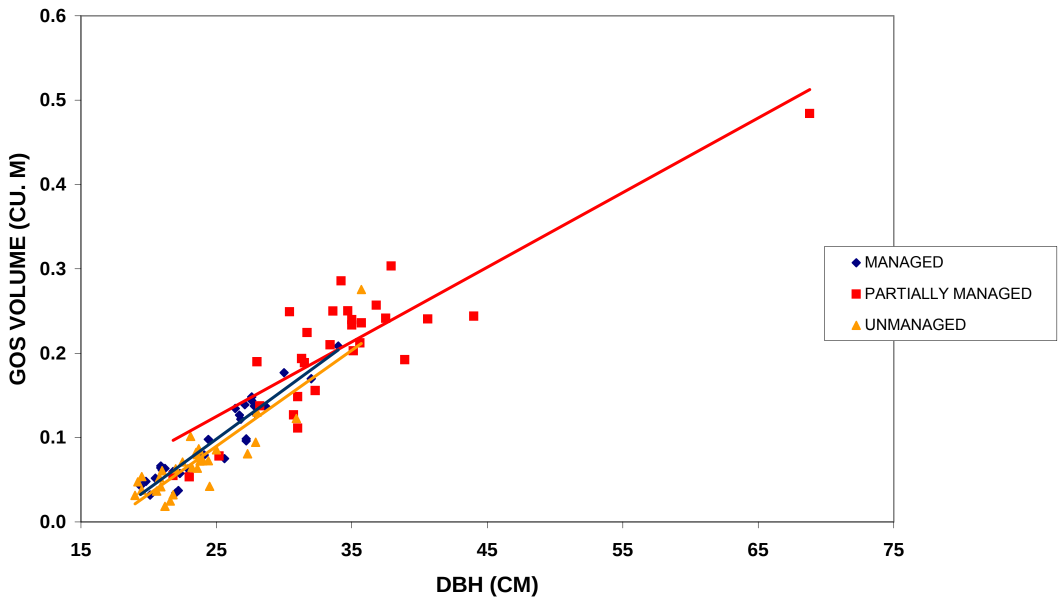


Figure 26. Relationship between DBH (cm) and GOS volume (m^3) at managed, partially managed and unmanaged sites in south west Queensland.

Dried graded recovery

Average dried graded recoveries for each site are shown in Table 9. Relative percentage recoveries of dried graded material by board size from the nine sites are shown in Table 10.

Table 10. Percentage of sawn dried graded boards from each site by size class.

Site	Board Width				Total (%)
	75mm	100mm	125mm	150mm	
1	2	34	22	42	100
2	5	47	26	23	100
3	59	24	12	5	100
4	9	37	33	21	100
5	7	42	25	26	100
6	11	45	26	18	100
7	16	35	24	24	100
8	8	20	9	51	100
9	19	38	28	17	100

At the eastern Queensland sites, management history had a significant impact on the linear relationship between DBH and DGR volume ($F_{2,76} = 12.4$, $P < 0.001$; Adj. $R^2 = 0.82$). An increase in tree diameter led to a significantly greater increase in DGR volume in the managed forest than in the partially managed or unmanaged forests (managed vs. partially managed: $t_{0.05,76} = 4.3$, $P < 0.001$; managed vs. unmanaged: $t_{0.05,76} = 4.3$, $P < 0.001$). The slopes for partially managed and unmanaged

sites were not significantly different ($t_{0.05,76} = 1.1$, $P = 0.297$) but their intercepts with the Y-axis were statistically different ($F_{2,78} = 14.7$, $P < 0.001$; $t_{0.05,78} = 2.4$, $P = 0.019$).
At the New South Wales sites, management history had no significant effect on the rate of increase in DGR relative to DBH ($F_{2,83} = 1.7$, $P = 0.188$), although the effect was significant after the exclusion of trees 93, 107 and 111 ($F_{2,80} = 8.0$, $P < 0.001$; Adj. $R^2 = 0.56$). All three logs were heavily butted for internal defect.

With these three logs excluded, significant differences between management types were apparent. The rate of increase in DGR volume at the managed and partially managed sites was significantly greater than the corresponding rate at the unmanaged site (managed vs. unmanaged: $t_{0.05,80} = 3.8$, $P < 0.001$; managed vs. unmanaged: $t_{0.05,80} = 2.3$, $P = 0.027$), although rate of increase in DGR volume at the managed site was not significantly different from that of the partially managed site ($t_{0.05,80} = 0.7$, $P = 0.505$). Note that only 56 % of total variation is explained by this model and there are small numbers of large diameter trees from each site that have high leverage. That is, they strongly influence the relationships between management types.

In south west Queensland there was no effect of management on the rate of increase in DGR volume ($F_{2,83} = 0.8$, $P = 0.435$). Slope intercepts for the partially managed and unmanaged sites were statistically different ($F_{2,85} = 3.4$, $P = 0.037$; $t_{0.05,85} = 2.6$, $P = 0.012$).

Data are shown in Figures 27, 28 and 29.

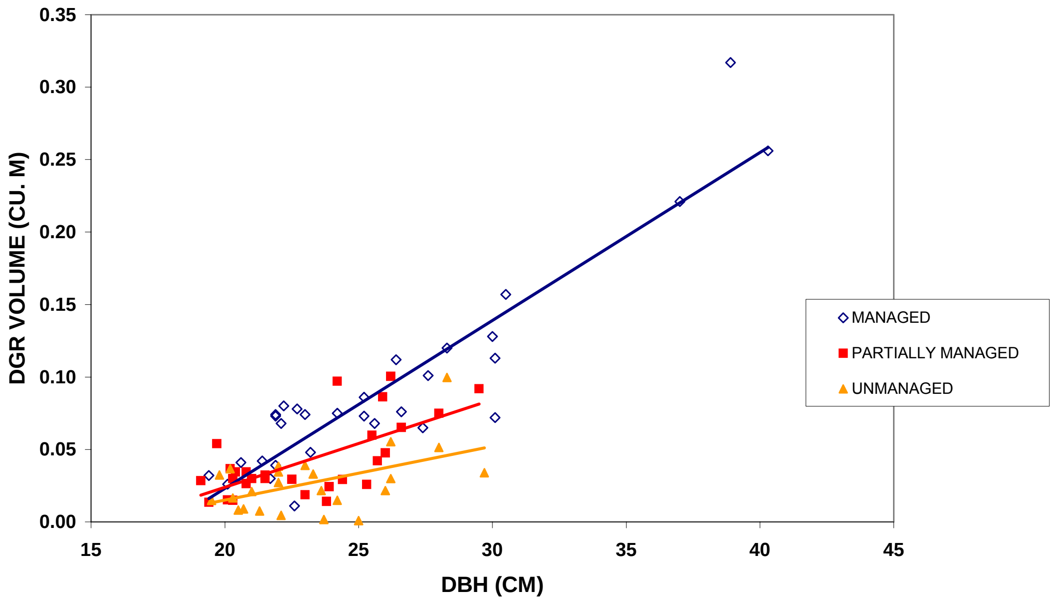


Figure 27. Relationship between DBH (cm) and DGR volume (m^3) at managed, partially managed and unmanaged sites in eastern Queensland.

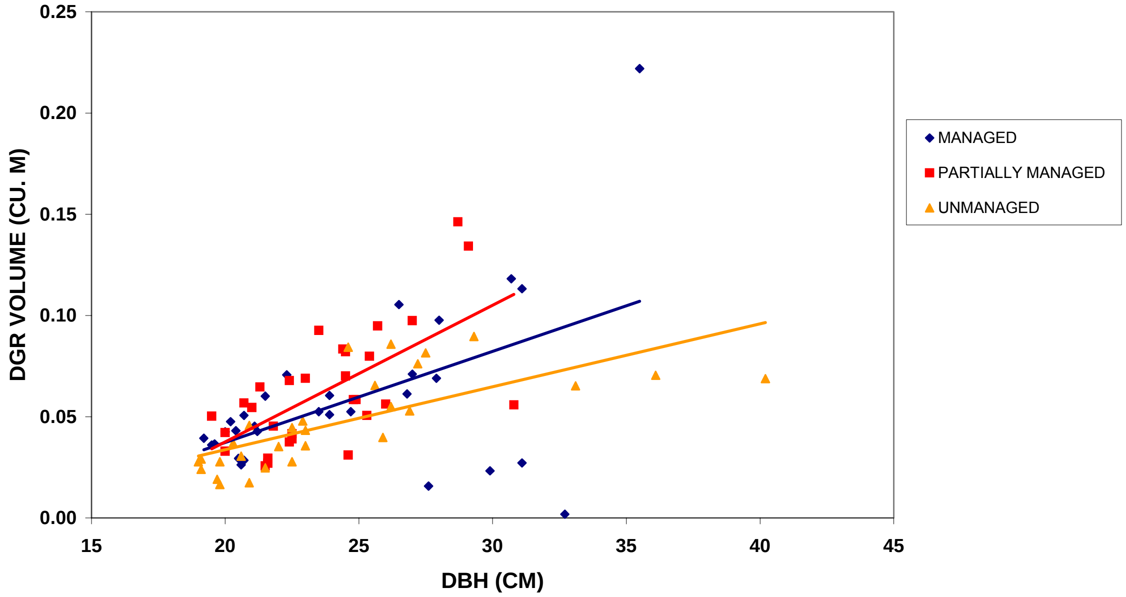


Figure 28. Relationship between DBH (cm) and DGR volume (m^3) at managed, partially managed and unmanaged sites in mid New South Wales after excluding trees 93, 107 and 111.

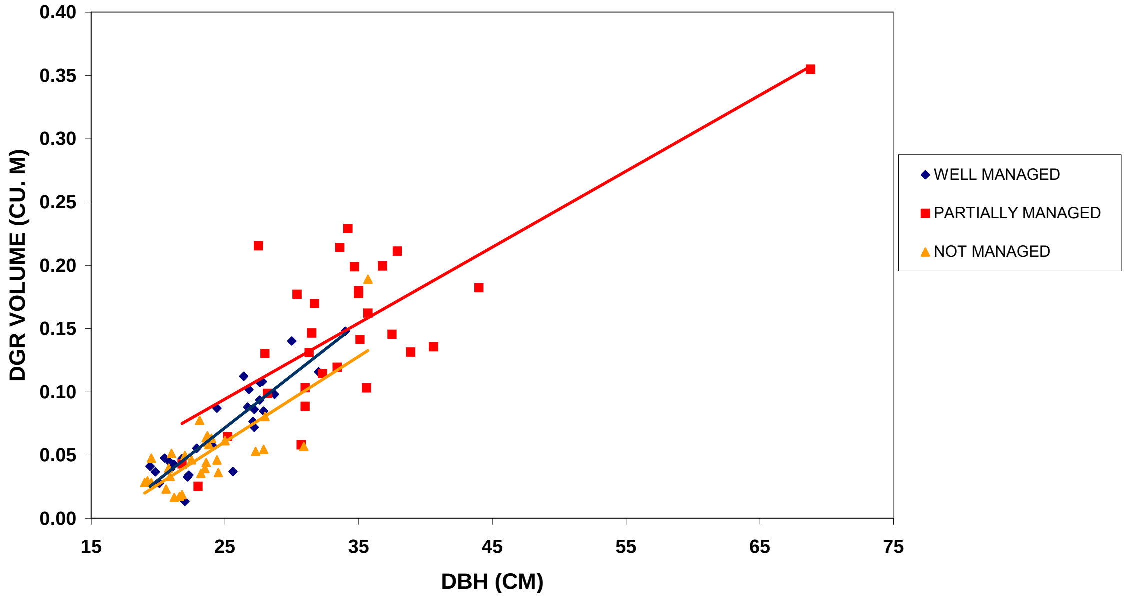


Figure 29. Relationship between DBH (cm) and DGR volume (m^3) at managed, partially managed and unmanaged sites in south west Queensland.

Defect

Defect from all logs was recorded both in the field and in the milling stage and defect from all sawn timber was assessed at both the GOS and DGR stage. No relationships between management history and defect were detected in this study at any of the levels assessed. There were a wide range of defects found in the study and these resulted from pest and disease fungi, physical damage to the tree prior to harvest and damage from handling in the harvest and processing stage.

Log defect - pests and decay fungi

There were a range of factors observed in this study causing log defect. These are listed below:

- Cypress bark weevil (Aesiotes)- Most, 95% of occurrence, was found in sites 1, 2 & 3. There were no detectible differences between management regimes.
- Cypress jewel beetle - The incidence of cypress jewel beetle damage was very low, about 1% for all trees. This beetle becomes a major problem after serious fires, storms or drought.
- Durabilla white grub – There was a higher incidence (twice) of DWG at sites 1, 2 & 3 in eastern Queensland than other sites and this is consistent with the observed distribution of DWG in the study. The partially managed site, site 2, had a much higher incidence than either site 1 or 3.
- Termites - About 9% of all trees harvested in the study were affected. There was no significant difference found between levels of management or locality.
- Decay - About 27% of all trees harvested in the study exhibited decay. Overall there was no significant difference found in the incidence of decay between different levels of management however the New South Wales sites exhibited two – three times the incidence of decay than Queensland sites. Out of 90 logs harvested in New South Wales, 24 were butted losing a total of 1.53 m^3. At sites 1 – 3 no logs were butted and at sites 7 & 8 butting was negligible, however 0.67 m^3 was butted from logs at site 9.
- Scars – Scarring was relatively minor at all sites and there was no difference between different levels of management or locality for scarring. Past physical damage from harvesting or fire is likely to cause scarring particularly in the butt of a tree.
- White line (sap crack) - The incidence of white line was highest at poorly managed sites, approximately six times the incidence at managed and partially managed sites. Overall 6% of trees were affected. White line was a significantly greater problem at the NSW sites, where 16% of trees were affected.

Relationships

There was a strong relationship observed between trees with scars and trees with decay. There was also a strong relationship observed between decay and termite occurrence with termite more likely to occur when there is decay present. Table 11 summarises the incidence of pests and decay fungi at the different localities.

Table 11. Numbers of trees from each site with observed defect type.

Site	Mgt. Regime	Aesiotes	White Grub	Termites	Jewel beetle	Decay	White line	Scars
1	Managed	9	2	3	0	2	0	7
2	Partial Mgt.	4	10	3	0	5	0	7
3	Unmanaged	8	9	0	1	3	0	11
Total		21	21	6	1	10	0	25
4	Managed	0	2	3	0	14	2	7
5	Partial Mgt.	0	10	0	0	11	3	7
6	Unmanaged	1	0	3	2	16	9	8
Total		1	12	6	2	41	14	22
7	Managed	0	2	2	0	4	0	5
8	Partial Mgt.	0	7	8	0	13	0	10
9	Unmanaged	0	0	1	2	5	2	6
Total		0	9	11	2	22	2	21

Timber defect

Sawn timber was assessed during the milling phase for a wide range of defect including:
want, wane, end splits, knots, injury, doze, resin, insect, heart shake, stain, bark encased knots, decay, split, distortion, sap-stain and fracture. No relationship was found in this study between forest management and timber defect.

Cause of defect in the sawing study, as a percentage of boards affected recorded at the DGR stage, is shown in Figures 30, 31 and 32.

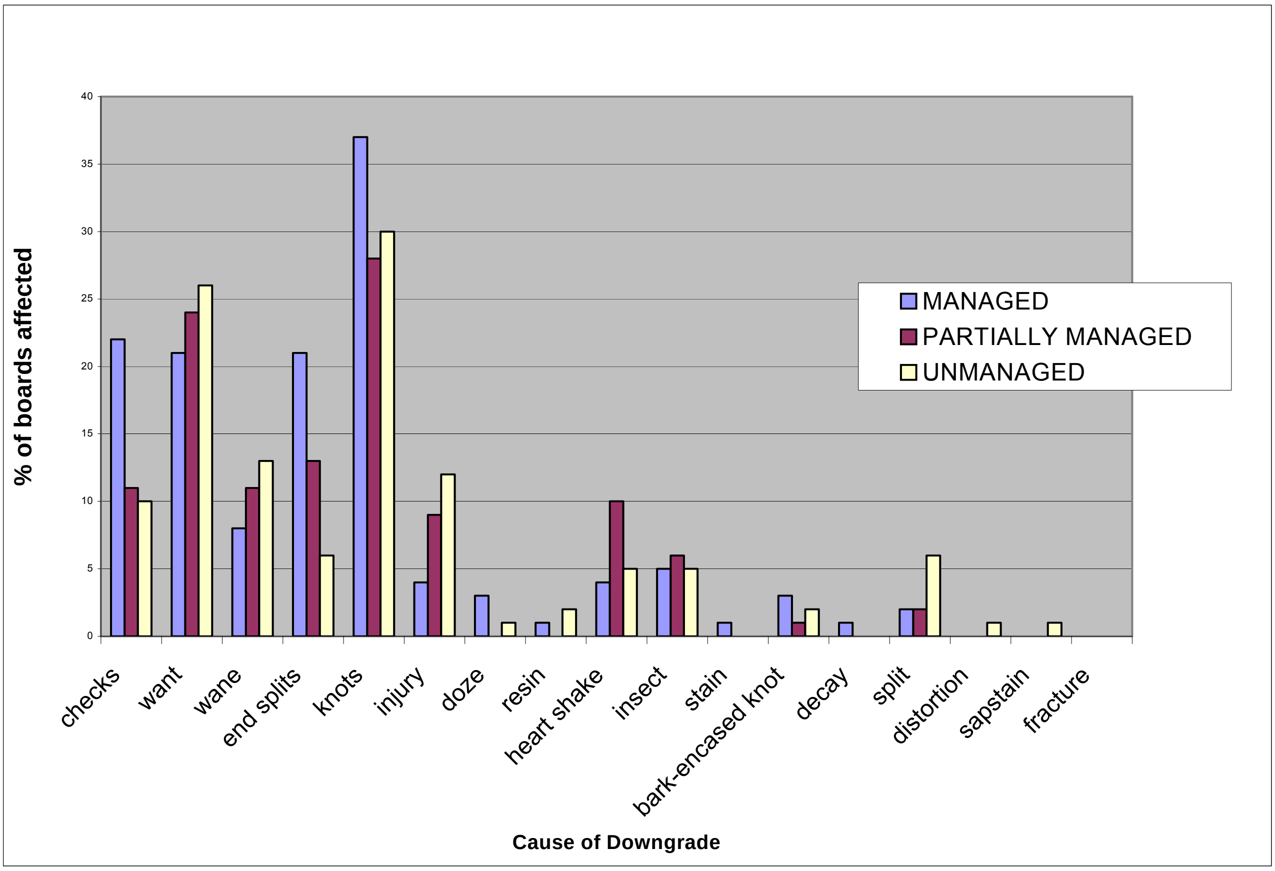


Figure 30. Percent of boards affected by defect type observed in boards from eastern Queensland sites at the DGR stage.

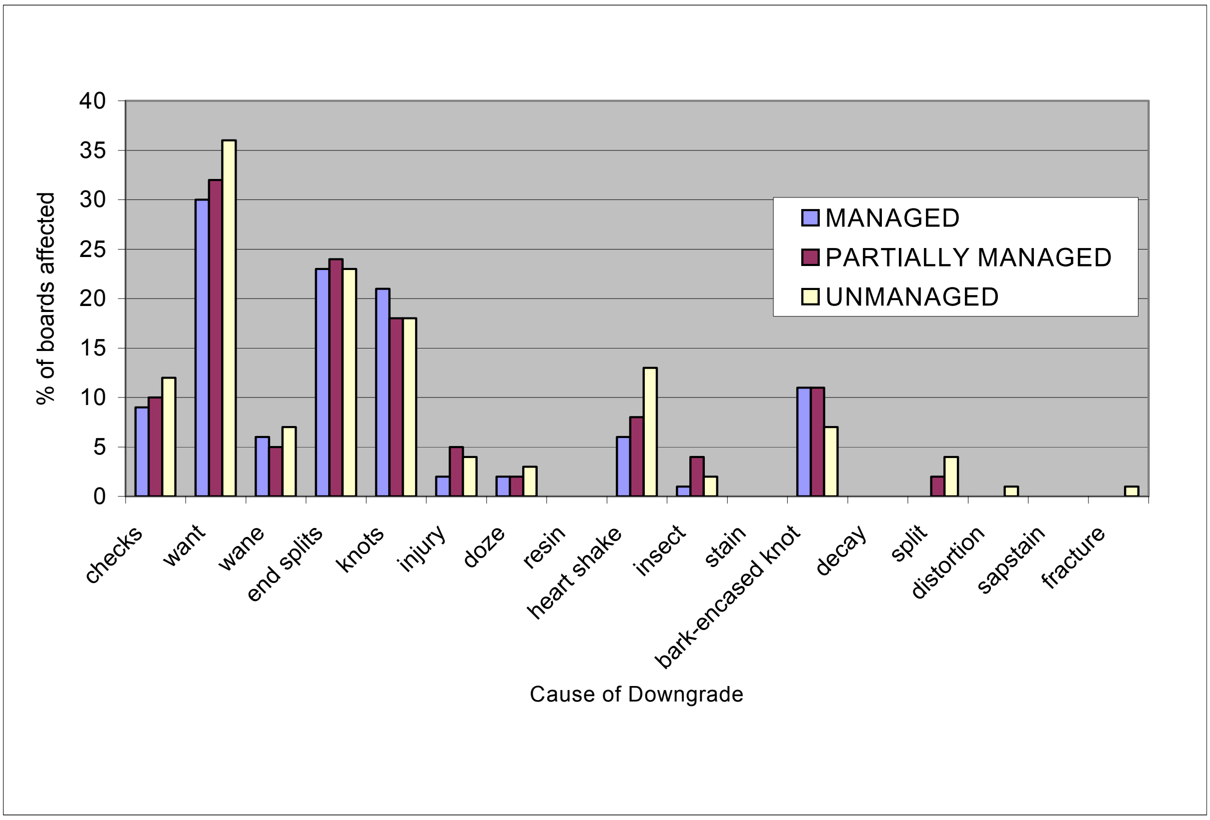


Figure 31. Percent of boards affected by defect type observed in boards from the New South Wales sites at the DGR stage.

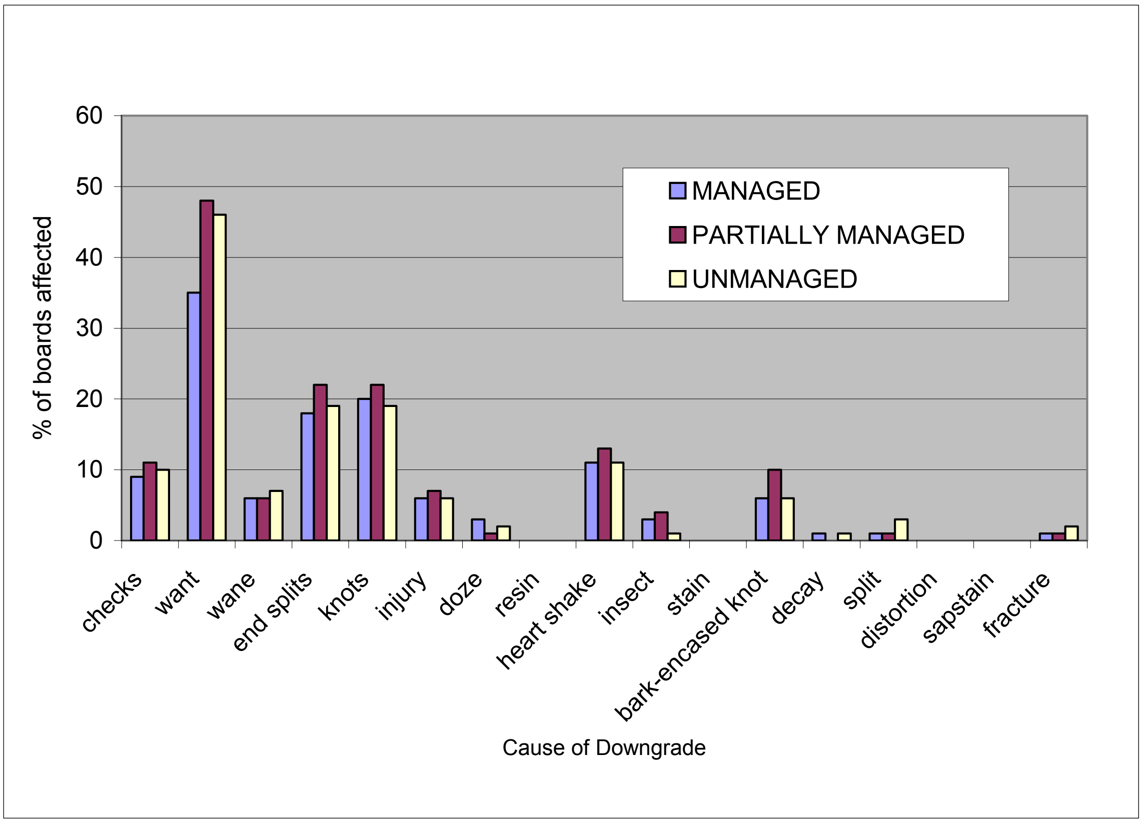


Figure 32. Percent of boards affected by defect type observed in boards from south west Queensland sites at the DGR stage.

Discussion

Sampling / stand types / tree size

The sampling regime endeavoured to select sites with similar site factors within each locality to minimise variation and enable comparison between the selected parameter, past management. Given the variation found in natural systems and the stand differences which are a function of management and stand history, this was difficult and the 'site form' relationship developed by Vanclay and Henry (1988) was used extensively in order to compare sites. This method utilises an 'index' of site, the height of a 25 cm DBH tree, to provide an estimate for comparison of sites for uneven-aged stands. This allows the combination of age and site productivity factors to be compared between sites to provide a relative ranking. Some differences were inevitable (Appendix 1) with the greatest difference within localities between sites 1 and 3 in eastern Queensland. The remaining sites can be considered comparable with minimal differences between site factors. This difference, in association with the sampling regime, was accounted for in the type of analysis performed where rates of change within individual sites were compared rather than gross differences.

The two other factors which influence relativity between sites, i.e., stand condition and trend and past silvicultural history, both affect the structure and composition of stands. Stand condition can be described in terms of stand structure, composition, age and history of development and this is generally referred to in terms of 'mature' or 'overmature' stands, regrowth stands or a combination the two. Mature stands generally are characterised by dominant large old senescent trees at relatively low density either in a mixed stand or as a pure white cypress stand. Most have an understorey or substratum of other species of younger, smaller sized trees which have regenerated and grown up to form a secondary layer. Other mature forests may be mixed and other species are codominant with the white cypress. Regrowth stands in white cypress are generally characterised by relatively dense stands of similar age class/es generally in smaller diameter sizes. Where these stands have been subject to silvicultural treatment, spatial arrangement and stocking may be altered to lower stocking in line with timber production objectives. Examples of this are the white cypress forests managed for timber production found on State forests such as those in the Pilliga in New South Wales or Barakula in Queensland.

Silvicultural management is essentially concerned with manipulation of the tree species within a stand, spatial arrangement / density and is generally a selection process. For the most part this concerns selection of trees to be retained as growing stock based on:

- Spatial arrangement – trees are thinned to a stocking which is generally a balance between site utilisation and commercial timber production,
- Tree form – trees with straight, long boles are retained, and,
- Tree vigour – trees which are actively growing are selected.

Significant research has established that silvicultural manipulation of stand parameters such as tree density and spatial configuration will manipulate stand size class distribution. Past thinning trials have demonstrated the link between diameter growth and tree spacing (Knott 1995, Johnson 1975, West 1990) and this has been evident from the sites sampled in this study. Tree stocking (Appendix 1) at each of the sample sites shows a higher percentage of trees in the larger size classes in the managed stands compared to the partially managed and unmanaged stands. Previous thinning and spatial arrangement has clearly resulted in a larger proportion of trees in the upper size classes.

The exceptions to this, however, are the two ‘mature’ stands, sites 6 & 8, where there is a proportion of larger size trees as a result of stand age rather than silvicultural manipulation. Younger regrowth stands, sites 3 & 9, both have a significant proportion of their tree stocking in the smaller size classes.

Log volume

In managed forests, early selection for desirable characteristics such as tree straightness and log length (form), vigour and optimum spacing will allow the selected trees to grow to potential. In the absence of selection, or selection only at harvest where past form is already realised, it is likely that less than optimal trees, i.e., trees that are shorter, have defects such as double stems, spiral grain or butt scarring, will develop in the stand thus lessening potential commercial log volume.

The difference in commercial log volume found in eastern Queensland (Figure 21) clearly shows the effects of silvicultural management, as all three stands are ‘regrowth’ stands of white cypress. The observed trend is towards a higher rate of increase in log volume relative to DBH in the managed site over partially managed and partially managed over unmanaged sites. While this is consistent with management effects, differences in ‘site factor’ between these sites may also have contributed to the trend.

At the New South Wales sites, the proportionally larger number of larger diameter trees sampled at site 4 (managed) should have produced an increase in log volume, relative to DBH, over the other two sites consistent with the eastern Queensland sites (Table 9, Figure 22). Results reveal a similar trend with DBH and log volume across all sites. It is likely that butting of logs at site 4 due to the higher incidence of internal decay (Table 11) at the managed site reduced any potential differences. The incidence of decay is associated with previous injury to trees and the more intensive silviculture associated with this site, where two previous thinnings have occurred, may have produced the increased decay through increased stem damage in the past. Anecdotal evidence also associates internal decay with poorly drained sites, however, this study was not able to establish this on the basis of sites sampled.

At the south western Queensland sites, there was also no discernable differences in trends for log volumes relative to tree DBH. Both sites 7 and 9, managed and unmanaged respectively, conform very closely in relation to DBH and log volume indicating there has been little advantage from past selection on the managed site. Site 8 has a similar trend to the other two sites and this is probably associated with increased defect, and subsequent butting at harvest, often found in large old 'overmature'(Florence 1996) trees sampled on this site. Fire was noted as relatively frequent at this site and this may account for the increased damage or internal decay found in these trees.

Both results from New South Wales and western Queensland contrast with those found in eastern Queensland. and contrast with the expected trend of an increase in log volume relative to DBH associated with management input.

Sawn recoveries

Green-off-saw recovery (GOS)

Green off saw recovery is affected by a range of factors including those associated with the log resource and those associated with the sawing technology (Williston 1981). In so far as the latter is concerned, processing all logs at the same mill and to the same product specifications reduced potential variation which may be found between sawmills with different sawing technologies or from different product recovery rates which may be influenced by sawing patterns or other factors. In this study, 25mm flooring boards were chosen as these represent a major part of the current market for many white cypress sawmills. By processing all logs at one sawmill and sawing for a particular product, the variation found in recovery rates was thus likely to be associated with differences in the log resource.

In their study of GOS recovery in *Pinus spp*., Knight *et al.* (1999) found that GOS recovery rates were primarily influenced by tree diameter, height, taper and tree straightness. Straight trees with larger diameters and less taper generally have higher GOS recoveries. GOS recovery in this study ranged from 30.2% to 41.9%, which is a lower range than the industry average (Roberts *et al* 2002) of 36 – 45% which results primarily from managed Crown resource.

With these factors in mind, GOS recovery was plotted as a function of tree diameter (DBH) and rates of increase in GOS were compared for differences between management regimes. Small diameter trees generally showed very little difference between management histories and this is most likely a function of limiting factors associated with sawn recovery from small logs. However, differences between treatments became apparent with increasing DBH. At the eastern Queensland sites, an increasing rate of recovery with tree size was found in trees from forests with a management history (Figure 24). Average GOS recovery rates of 41%, 34.3% and 30.2 % respectively for managed, partially managed and unmanaged sample sites underline an increasing rate of recovery with increasing DBH associated with past forest management. These results were consistent with the New South Wales sites (Figure 25), where sites 4 (av. 41.6%) and 5 (av. 41.9%), both of which have a management history, showed an increasing rate of GOS recovery over the unmanaged stand at site 6 (av. 34.3%) after logs with significant volumes butted due to internal defect were excluded.

These results contrast with those from sites 7, 8 and 9 in south west Queensland (Figure 26) where no significant differences were found between management types in GOS recovery. At these sites, average GOS recovery rates were 39.7%, 40.2% and 40.0% respectively for managed, partially managed and unmanaged. This is possibly explained by the apparent high site quality of site 9. GOS recoveries from site 9 were expected to be below those of sites 7 and 8 as site 7 has a long history of silvicultural management and site 8 is an 'overmature' forest with a stocking of trees in the larger diameter classes. Stocking levels at site 9 (Appendix 1) showed a very high stocking of trees in the commercial diameter classes (19cm DBH+) relative to all other sites and this indicates that site factors may be masking the usual effects associated with lack of management such as poor form and small size.

Given that the major influences found in other studies (Hillis and Brown 1984, Williston 1981) affecting GOS recovery were tree diameter, height and straightness, it was expected that trees subjected to past management have improved recoveries and this was found at two localities. Management is essentially concerned with a selection process where trees are selected on spacing, form and vigour. In terms of spacing, selection and thinning to an acceptable density promotes increased individual tree size over total volume production. Tree size is generally a function of tree density and site factors. In white cypress forests, the prolific regeneration and subsequent dense stands often preclude large tree sizes and stands without thinning become subject to 'lockup' where mortality and growth rates are minimal (West nd). In the absence of intervention this can continue indefinitely and trees may not reach commercial size until very old.

Dried graded recovery (DGR)

While the major benefits of forest management, such as tree form and growth, are thought to impact on GOS recovery, it is apparent from DGR results in this study that some of the benefits of management have carried through to the secondary processing stage. At the eastern Queensland and New South Wales sites, significant differences were found between management types with increasing DGR relative to DBH at eastern Queensland and New South Wales localities. At sites 1, 2, and 3 (eastern Queensland), increasing DBH produced a significantly increased dried graded recovery at the well managed site compared to partial and nil management sites and the same trend occurred in logs from sites 4, 5 and 6 (New South Wales) where significant increases in DGR were found for the two managed sites (4 & 5) over the unmanaged site (6) with increased tree size. Similar to GOS results, these results contrast with results found at sites 7, 8 and 9 in south west Queensland where no differences in DGR were found between management histories.

This must again be attributed to factors other than management, and, as discussed above, may be an artefact of the increased variation in recoveries found in the overmature forest at site 8 and the high site quality at site 9. Site 7 is regarded by industry as a high quality site, in terms of returns from past timber harvests, and this site has been subject to silvicultural management for some time. As well, given the high average log volume sampled at site 8, a higher GOS and DGR were expected than that achieved. The average levels achieved are probably associated with the higher levels of defect generally found in large old trees. The higher DGR levels from site 9 are consistent with the GOS results and must be attributed to site factors. The site history obtained from the landholder indicated fire exclusion since the regrowth initiated in the 1930s and this has likely reduced stem damage and subsequent defect development. The relatively high tree densities found on this site are not consistent with results from other sites and it is likely that severe inter-tree competition is occurring.

The percentage increases found in DGR from logs from managed forests over partial and unmanaged forests (Table 10), with the exception of sites 7, 8 and 9, reflect an increase in log quality, at least in terms of sawn timber quality, and by implication, a reduction in the incidence of internal log defect. This is likely to be associated with management selection of defect free trees initially and protection from damaging factors, such as fire and harvest damage, which allow entry of pathogens, such as decay fungi and beetles, into the logs. Early espacement is also likely to contribute to timber quality in terms of tree health, branch size and growing conditions.

DGR is generally affected by a number of different factors to those that influence GOS recovery although factors such as log taper may also affect recovery through wane[5]. Internal defects found in the logs such as knots, splits, decay and resin, impact on wood quality to a greater extent. The results from this study did not reveal any relationship between management regimes and defects recorded at

[5] Wane applies to the absence of wood in a cross section of board due to the natural curvature of the outer growth of the tree.

the DGR stage, however, analysis did not look at individual defect types. Sites which have had more intensive management in the past may well have higher levels of physical damage to remaining trees from harvesting practice than unmanaged sites, depending on the quality of management. This may explain the log volume butted from harvested logs at site 4, New South Wales, where 0.781 m^3 was removed. However, many unmanaged sites are exposed to fire at some through their life cycle and this also promotes physical damage and subsequent defect development.

At all sites in this study, the majority of defect found at the DGR stage resulted from wane, knots, checks, end splits and want [6]. As discussed above, wane is a function of log taper in many cases and this is related to the small tree size and height. It was initially thought that large branches often found in open-grown trees or unmanaged sites may have contributed to higher levels of defect through bark encased knots and other faults, however, this was not detected in this study. Knots resulted in similar defect levels across all management types and may be a function of factors other than management effects. The other major causes of observed defect at the DGR stage, checks and end splits, are associated with drying of timber. This type of defect is accepted as a normal part of the drying process and it would appear that further research work on drying schedules may improve DGR. The other significant cause of defect, want, is a result of mechanical damage and this will vary between mills and processing technology.

Defect from insects and decay fungi

As discussed above, different types of defect have different influences on timber recovery in the processing chain. In this study the most significant losses from defect were from butting logs at harvest because of internal decay. Three percent of the volume of harvested logs was butted and left in the field, most from the New South Wales sites and some from south west Queensland. Further losses occurred in the processing stage where undetected decay became apparent once the logs were sawn. A total of 41 logs out of 90 harvested were recorded as containing decay at the New South Wales sites with 14, 11 and 16 logs (out of the 30 harvested at each site) affected from the managed, partially managed and unmanaged respectively. This study was unable to determine cause of decay in the trees however this incidence is unlikely to be a result of past physical damage and may be associated with site characteristics of the area.

However in most situations entry of pests and disease is facilitated by physical damage. Therefore it is essential during controlled burning, logging, thinning or other management operations, that physical damage to the trees is kept to a minimum. This will reduce the incidence of scars and entry points to pests and decay fungi and subsequently the associated insect damage and decay.

Insect damage was not found to be a serious problem in this study and insect damage, particularly from Durabilla white grub, did not reach levels found at other sites in eastern Queensland. It is thought that the more serious examples of insect damage found in the industry may be due to high concentrations of insects in defined areas and does not represent a major problem to the wider white cypress industry. In areas where localised occurrences of insects are known to occur, assessment of the sites needs to be undertaken prior to investment in management.

[6] Want is the absence of wood in a cross section of board due to mechanical damage, such as forklift handling.

Conclusions

The white cypress industry has been in a state of change for some time. Competition in the traditional domestic market place, development of new markets, rationalisation of the growing and processing industry and more lately pressure on the resource for conservation purposes is changing the face of the industry. In many ways the industry has a bright future. The timber is naturally termite resistant and consumers are seeking more ‘natural’ products. The overseas demand for feature quality white cypress product is increasing. It is also an important regional industry producing a unique timber. Many of the small regional communities are reliant on the sawmills for their continued viability and these go towards maintaining a network of regional infrastructure.

However, the industry must look to the future. The perceived increase in public pressure towards changing forests originally reserved for timber production to conservation oriented outcomes is influencing decision makers despite the very long management history of many white cypress forests. As well, the last decade in Queensland has seen a much increased rate of tree clearing on private land and considerable quantities of high quality white cypress forest have been lost. As many in agricultural will attest, white cypress forests are resilient and there is great opportunity for many landholders to manage the developing regrowth forests towards a dual purpose, that of grazing and timber production. Support by existing industry will be crucial in achieving this.

This study has reviewed aspects of the white cypress resource and industry and investigated the relationship between log resource and production of high quality sawn timber. Some implications for industry are:

- White cypress forest resource – The majority of the industry is based on Crown resource, nearly 100% in New South Wales and approximately 75%in Queensland with a declining harvest from private land in both states. Very little management for timber production is practiced on private land in white cypress forests and there is a declining amount carried out on Crown land. For the most part, timber stands inspected on private land during this project were unmanaged. The majority were younger sub-commercial regrowth stands which have the potential to provide substantial log resource in the future if managed. In the absence of management intervention these stands may not provide quality commercial logs the processing industry is seeking. In the stands containing commercial trees, many were either unmanaged or poorly managed, yielding low value product. Few stands were inspected that were producing the high quality trees sought after by sawmillers. Generally, most landholders cited a lack of information on management, poor economics and resource security issues as reasons for not managing their timber resource. With support from existing industry, such as managing future growing stock through harvesting practice and potentially becoming involved in early thinning, the resource on private land can improved substantially over time thus complementing / supplementing Crown resource.

- White cypress has a wide distribution, however, current remote sensing techniques and inventory information is unable to provide an accurate estimate of resource availability and commercial volumes on private land. Inventory information on State land is extensive as both New South Wales and Queensland are undergoing reviews including white cypress forest resources. The recent spate of tree clearing in Queensland has included large areas of white cypress forest and an accurate estimate of the current extent of the resource outside of Crown lands is unknown. Planning for future resource management is difficult without such information.

- In terms of sawn timber recoveries from managed forests, this study has shown that two of the three sites sampled exhibited significant increases in both green-off- saw and dried graded recoveries from managed forests to unmanaged forests. This has economic implications for both sawmillers and forest owners. In the long term, the cessation of intensive management on State lands will impact on resource quality and availability. The association between defect and past injury also needs to be addressed at the management level and reduction in butt damage by careful harvest methods and protection from fire damage will ensure fewer entry points for pests and decay fungi.

- At the dried graded stage, the majority of downgrade was due to a small number of factors including wane, want, knots, checks, and end splits. Some of these, checks and end splits, may be improved with a closer investigation of kiln drying schedules to avoid too rapid drying. Other aspects such as wane, knots and decay may be more a cause of or can be remedied by forest management, where selection of commercially more desirable trees in the forest management stage, i.e., straighter, well spaced and defect free trees, may yield a better log which in turn yields higher green-off-saw and dried graded recoveries.

- Future programs of research should consider drying schedule development to minimise surface checking, utilisation of residues including residues from forest management activities such as thinning and development of products from 75 x 25 mm section material.

- Selection for form and vigour involves retaining trees with both good bole length and straightness to promote a high quality future log which has the capacity for fast growth. White cypress is generally not very tall in comparison to other commercial tree species and log length and thus taper may form a major influence on green-off-saw recovery levels. In this study neither straightness nor taper measurements were made and this may be an important criteria for future work when assessing tree form for sawn recoveries.

- The major insect pests and decay fungi were described. Of these, the cypress jewel beetle and brown rot were the most important in terms of damage to logs. Physical damage either through natural causes such as stress or fire or damage through harvesting provides entry points. Damage from the jewel beetle is generally evident in the short term however entry of decay fungi may not be evident for many years and care needs to be taken to avoid damage to the valuable butt section of future commercial trees.

- In the course of this study, sites with severe infestations of Durabilla white grub were encountered although none of the trees harvested from the nine sites contained serious insect damage. Where serious insect damage is known to occur, care should be taken in the selection of areas for intensive management to ensure that returns from investment are maximised.

- Generally, high quality white cypress sites with a good potential to grow commercially more desirable trees, (sites with high site factors, eg > 14 - 15m) should be selected for management over lower, less productive sites. Silvicultural management guides are currently available in both States to provide guidelines for landowners in relation to both management for commercial timber production and management for environmental outcomes. Good management will ensure future logs will be in line with industry requirements to provide a high quality sawn product thus enabling both forest growers and processors to maximise economic returns.

Appendices

Appendix 1 - Site descriptions

Site descriptions are provided below. More detailed site descriptions have been included in previous milestone reports for this project (Taylor *et al* 2000). Salient points for each site are presented below (Table 1).

Site 1 – Managed stand - Barakula State forest

The site was a managed pure white cypress stand subject to two past harvests and three silvicultural thinning operations since the 1930s. The site has also been protected from fire in the past. Soil is an Arenic Rudosol (Isbell, 1996) with loamy sand to 50 cm over fine sandy clay.

Site 2 – Partially managed stand - Freehold land south west of Miles

The site was a mixed white cypress / narrow leaf red ironbark forest which has been subject to management for timber production in that selective harvesting has been undertaken at intervals since 1950 and fire has been excluded. No thinning has occurred and thus the site can be considered partially managed. Soil is an Arenic Rudosol (Isbell 1996) with a deep fine sandy loam to 1.0 m +.

Site 3 – Unmanaged stand - Freehold land south west of Miles

The site was a mixed white cypress / narrow leaf red ironbark forest with regrowth white cypress. There has been no past management for timber production and evidence of only one past harvest for fencing timber. The area is grazed and not subject to regular fire. Soil is a Brown Kandosol (Isbell 1996) with a deep fine sandy clay loam to 90 cm +.

Site 4 – Managed stand – Cpt. 387 Yearinen State forest, Baradine

The site was a pure white cypress stand resulting from 1890s regeneration. Some regrowth eucalypts are present. Fire has been excluded. This site was first thinned in 1940 to 629 / ha and again in 1982 to 500 / ha. Soil is an Arenic Rudosol (Isbell 1996) with a loamy sand to 50 cm over a clayey coarse sand to 1.0 m +.

Site 5 – Partially managed stand – Cpt. 387 Yearinen State forest, Baradine

The site was the same stand and soil type as for Site 4 with the exception of thinning history. This stand was thinned once in 1940 to 639 / ha and left. In relative terms it could be argued that this stand is a managed stand however for the purposes of this study and to compare relative differences, the site has been described as partially managed.

Site 6 – Unmanaged stand - Cpt. 388 Yearinen State forest, Baradine.

This site is a mixed white cypress – eucalypt forest located in a firebreak. The forest is silviculturally unmanaged and may have had a single harvest in the past. Large old white cypress trees (> 40 cm DBH) are common. There is evidence of past fires. Soil is an Arenic Rudosol (Isbell 1996) with loamy coarse sand to 60 cm over a clayey coarse sand to 1.0 m +.

Site 7 – Managed stand - Cpt. 2 Umbercollie State forest.

This site is in a silviculturally well managed pure white cypress stand resulting from thinning and selective harvesting since the early 1900s. The last harvest occurred in 1974. Soil is a Brown Kandosol (Isbell 1996) with a fine sandy loam to 45 cm over a medium clay.

Site 8 – Partially managed stand - Forest Entitlement Area 44, (Leasehold).

This site is a mixed white cypress – carbeen stand with little past management history. It has been allocated as 'partially managed' for the purpose of this study as it represents a very different structure to sites 7 and 9. A selective harvest is thought to have occurred in the late 1950s – early 1960s and this is evidenced by scattered stumps. The stand comprises a two-tier stand with an overstorey of very large old mature trees and young regrowth. Fire has been relatively frequent. Soil is an Arenic Rudosol (Isbell 1996) with fine loamy sand to 1.0 m +.

Site 9 – Unmanaged stand - Leasehold Land

This site was an unmanaged pure white cypress stand, likely to be a regrowth stand from the 1930s. A single harvest for fencing timber was conducted prior to selection of the site for the trial. With this exception, no other management has occurred and the stand had been protected from fire. Soil is an Arenic Rudosol (Isbell 1996) with fine loamy sand to 1.0 m +.

A summary of sites details are listed below (Table 1).

Table 1. Sample site locations.

Site Number	Location	Management Type	Forest Type
1	State forest 302, Barakula	Managed	Pure cypress regrowth
2	Freehold Land	Partial Managmentt	Mixed eucalypt / cypress regrowth
3	Freehold land	Nil management	Mixed eucalypt / cypress regrowth
4	Yearinan State forest, Pilliga	Managed*	1890s Cypress regrowth - some eucalypt
5	Yearinan State forest, Pilliga	Managed*	1890s Cypress regrowth – some eucalypt
6	Yearinan State forest, Pilliga	Nil management.	1890s Cypress regrowth – some eucalypt.
7	Umbercollie State forest	Managed	Cypress & some eucalypt regrowth
8	Leasehold land	Partial management	Mixed cypress / eucalypt woodland
9	Leasehold land	Nil management	Regrowth Cypress stand

* - Differences between sites 4 & 5 are based on past silvicultural regimes. Site 4 has had a more intensive management applied.

Stand details

Stand inventory was assessed using temporary 1/20 ha plots subjectively located in the sample area to cover the observed variation. Stand densities are shown in Table 2 & 3 and Figures 1, 2 and 3.

Table 2. Stand inventory data expressed on a per hectare basis for white cypress >10 cm + DBH at each site.

Site	Diameter Class (cm DBH)						Site Form$^{\varnothing}$
	10 – 19.9	20 - 29.9	30 - 39.9	40 - 49.9	50.0 +	Total	
1	110	165	55	0	0	330	17.7
2	260	165	0	0	0	425	16.1
3	325	70	0	0	0	395	14.9
4	147	407	33	0	0	587	15.2
5	340	240	0	0	0	580	16
6	375	150	5	10	0	540	16.1
7	45	250	25	0	0	320	16
8	20	80	125	10	0	235	17
9	460	280	5	0	0	745	16

BA = Basal Area

$^{\varnothing}$ = Site Form refers to the height in metres of a white cypress approx. 25 cm DBH

Table 3. Other species numbers / ha and basal area (BA) by site.

Site	Other Species > 10 cm DBH / ha	Cypress pine BA / ha (m^2)	Total BA / ha (m^2)
1	34	-	16.15
2	194	-	25.9
3	26	-	14.5
4	160	25.2	26.3
5	155	19.9	24.4
6	250	15.5	26.0
7	105	15.9	16.3
8	45	18.4	24.9
9	5	21.8	22.4

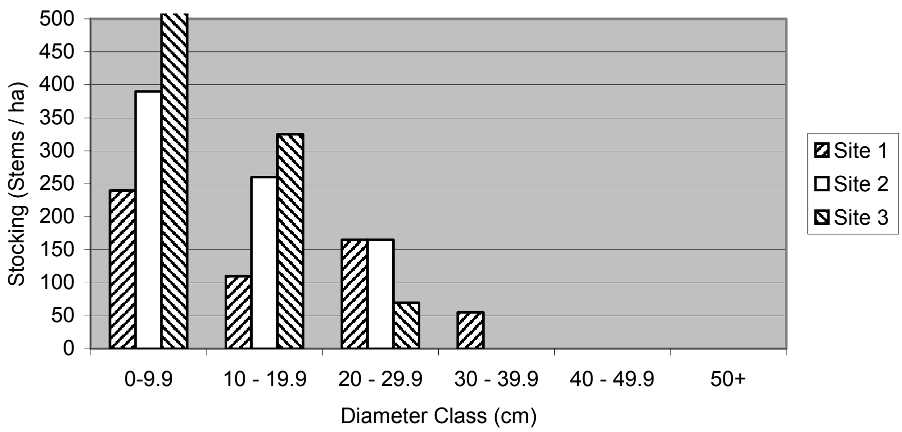


Figure 1. Stand table (White cypress stems > 10 cm DBH / ha by DBH class) for sites 1, 2 & 3, eastern Queensland.

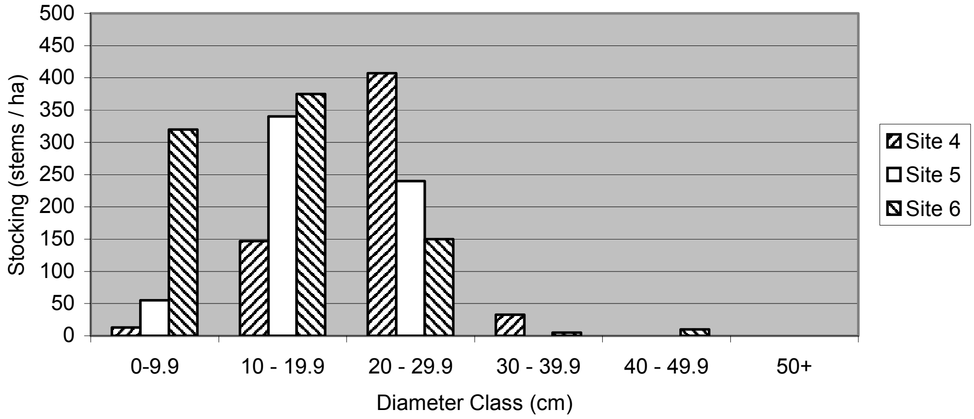


Figure 2. Stand table (White cypress stems > 10 cm DBH / ha by DBH class) for sites 4, 5 & 6, in New South Wales.

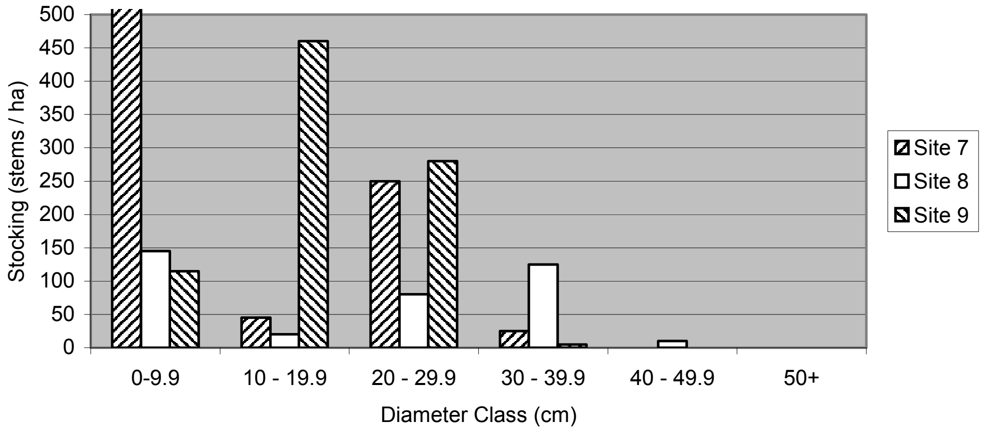


Figure 3. Stand table (White cypress stems > 10 cm DBH / ha by DBH class) for sites 7, 8 & 9, south western Queensland.

Appendix 2 - Log volume, green off saw (GOS) and dried graded volume (DGV) for all sites.

Site 1

Tree No	LOG VOL	GOS VOL	DGV
1	0.343	0.148	0.12
2	0.168	0.058	0.042
3	0.125	0.050	0.026
4	0.931	0.424	0.256
5	0.327	0.127	0.101
6	0.272	0.093	0.075
7	0.196	0.080	0.073
8	0.286	0.111	0.086
9	0.174	0.092	0.08
10	0.289	0.112	0.073
11	0.274	0.096	0.068
12	0.436	0.187	0.128
13	0.209	0.063	0.039
14	0.362	0.151	0.112
15	0.188	0.085	0.074
16	0.407	0.183	0.157
17	0.183	0.062	0.041
18	0.098	0.035	0.032
19	0.226	0.0345	0.011
20	0.468	0.194	0.072
21	0.219	0.097	0.078
22	0.340	0.139	0.076
23	0.179	0.081	0.068
24	0.190	0.068	0.03
25	0.195	0.095	0.074
26	0.276	0.101	0.065
27	0.405	0.167	0.113
28	0.197	0.073	0.048
29	0.902	0.425	0.317
30	0.641	0.291	0.221
Site 1	**9.507**	**3.924**	**2.756**
%		41.270	28.98

Site 2

Tree No	LOG VOL	GOS VOL	DGV
31	0.190	0.059	0.030
32	0.135	0.045	0.035
33	0.132	0.046	0.014
34	0.263	0.102	0.026
35	0.132	0.058	0.054
36	0.120	0.048	0.029
37	0.124	0.051	0.015
38	0.273	0.107	0.097
39	0.191	0.070	0.014
40	0.318	0.130	0.092
41	0.251	0.104	0.060
42	0.223	0.079	0.042
43	0.261	0.077	0.029
44	0.145	0.055	0.037
45	0.243	0.086	0.024
46	0.158	0.047	0.032
47	0.353	0.050	
48	0.136	0.046	
49	0.128	0.047	0.030
50	0.363	0.084	0.065
51	0.250	0.071	0.019
52	0.149	0.065	0.026
53	0.169	0.060	0.029
54	0.143	0.050	0.035
55	0.303	0.109	0.101
56	0.342	0.115	0.048
57	0.320	0.115	0.086
58	0.327	0.126	0.075
59	0.175	0.064	0.030
60	0.114	0.024	0.015
Site 2	**6.430**	**2.187**	**1.188**
		34.000	18.470

Site 3

Tree No	LOG VOL	GOS VOL	DGV
61	0.151	0.053	0.030
62	0.205	0.049	0.001
63	0.157	0.053	0.022
64	0.115	0.043	0.037
65	0.125	0.045	
66	0.096	0.040	0.032
67	0.175	0.021	
68	0.163	0.028	0.002
69	0.301	0.122	0.100
70	0.096	0.018	0.008
71	0.227	0.083	0.055
72	0.109	0.035	0.027
73	0.082	0.031	
74	0.101	0.039	0.017
75	0.096	0.028	0.021
76	0.112	0.020	0.009
77	0.096	0.023	0.005
78	0.074	0.029	0.015
79	0.121	0.026	
80	0.082	0.036	0.034
81	0.141	0.056	0.038
82	0.115	0.040	0.033
83	0.168	0.050	0.035
84	0.166	0.074	
85	0.197	0.051	0.022
86	0.155	0.059	0.039
87	0.278	0.088	0.051
88	0.213	0.056	0.015
89	0.103	0.015	0.008
90	0.112		
Site 3	**4.333**	**1.308**	**0.654**
		30.180	15.090

Site 4

Tree No	LOG VOL	GOS VOL	DGV
91	0.193	0.078	0.053
92	0.108	0.047	0.026
93	0.114	0.047	0.023
94	0.154	0.043	0.029
95	0.139	0.044	0.029
96	0.345	0.131	0.069
97	0.125	0.054	0.043
98	0.347	0.148	0.113
99	0.110	0.039	0.037
100	0.141	0.060	0.045
101	0.277	0.128	0.098
102	0.522	0.265	0.222
103	0.202	0.103	0.061
104	0.124	0.041	0.039
105	0.186	0.083	0.071
106	0.103	0.041	0.036
107	0.127	0.050	0.027
108	0.135	0.054	0.048
109	0.128	0.049	0.043
110	0.248	0.095	0.071
111	0.134	0.019	0.002
112	0.223	0.091	0.061
113	0.158	0.051	0.043
114	0.169	0.071	0.060
115	0.134	0.060	0.051
116	0.420	0.216	0.118
117	0.288	0.140	0.016
118	0.279	0.115	0.105
119	0.197	0.084	0.051
120	0.165	0.077	0.053
Site 4	**5.997**	**2.525**	**1.742**
		42.100	29.040

Site 5

Tree No	LOG VOL	GOS VOL	DGV
121	0.213	0.081	0.051
122	0.191	0.083	0.059
123	0.109	0.045	0.033
124	0.197	0.079	0.069
125	0.118	0.045	0.042
126	0.224	0.083	0.042
127	0.355	0.157	0.056
128	0.151	0.069	0.039
129	0.346	0.147	0.098
130	0.163	0.060	0.055
131	0.123	0.056	0.050
132	0.295	0.123	0.080
133	0.207	0.081	0.065
134	0.139	0.044	0.030
135	0.221	0.104	0.093
136	0.392	0.175	0.146
137	0.126	0.038	0.027
138	0.192	0.083	0.070
139	0.164	0.056	0.031
140	0.288	0.136	0.134
141	0.171	0.054	0.026
142	0.139	0.060	0.057
143	0.173	0.073	0.068
144	0.164	0.068	0.045
145	0.247	0.109	0.083
146	0.197	0.073	0.038
147	0.286	0.094	0.082
148	0.191	0.075	0.056
149	0.224	0.095	0.059
150	0.222	0.112	0.095
Site 5	**6.228**	**2.558**	**1.876**
		41.070	30.120

Site 6

Tree No	LOG VOL	GOS VOL	DGV
151	0.105	0.037	0.028
152	0.101	0.071	0.029
153	0.078	0.027	0.024
154	0.239	0.067	0.055
155	0.388	0.131	0.065
156	0.289	0.122	0.076
157	0.198	0.068	0.043
158	0.199	0.060	0.028
159	0.308	0.121	0.090
160	0.272	0.114	0.084
161	0.241	0.071	0.065
162	0.146	0.046	0.017
163	0.110	0.051	0.035
164	0.238	0.081	0.053
165	0.225	0.058	0.036
166	0.280	0.113	0.082
167	0.191	0.059	0.048
168	0.118	0.039	0.039
169	0.165	0.074	0.046
170	0.087	0.037	0.028
171	0.108	0.045	0.037
172	0.172	0.070	0.045
173	0.287	0.109	0.086
174	0.100	0.032	0.017
175	0.359	0.130	0.071
176	0.086	0.023	0.019
177	0.134	0.048	0.031
178	0.237	0.057	0.040
179	0.200	0.041	0.025
180	0.737	0.164	0.069
Site 6	**6.398**	**2.164**	**1.408**
		33.820	22.000

Site 7

Tree No	LOG VOL	GOS VOL	DGV
181	0.310	0.137	0.108
182	0.270	0.099	0.086
183	0.237	0.096	0.072
184	0.118	0.052	0.048
185	0.319	0.139	0.077
186	0.176	0.060	0.047
187	0.157	0.064	0.044
188	0.165	0.066	0.039
189	0.214	0.098	0.087
190	0.274	0.127	0.088
191	0.391	0.144	0.094
192	0.333	0.128	0.085
193	0.125	0.032	0.028
194	0.119	0.035	0.014
195	0.148	0.037	0.033
196	0.570	0.209	0.148
197	0.247	0.075	0.037
198	0.154	0.062	0.041
199	0.342	0.134	0.112
200	0.302	0.136	0.098
201	0.148	0.063	0.043
202	0.337	0.148	0.107
203	0.155	0.057	0.034
204	0.291	0.122	0.102
205	0.147	0.063	0.055
206	0.125	0.043	0.041
207	0.167	0.079	0.057
208	0.119	0.048	0.037
209	0.369	0.170	0.116
210	0.433	0.177	0.140
Site 7	**7.26**	**2.90**	**2.12**
		39.940	29.200

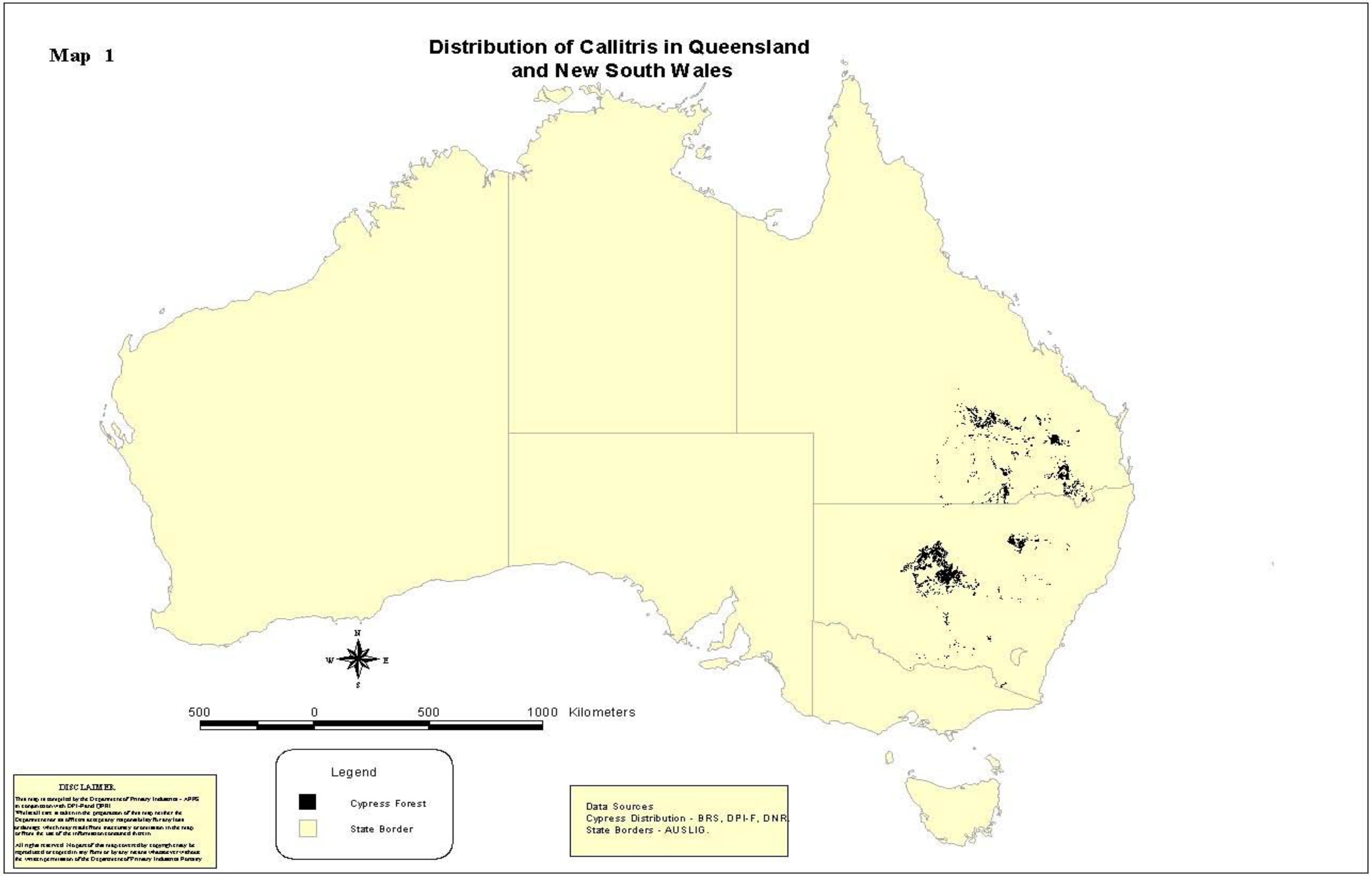
Site 8

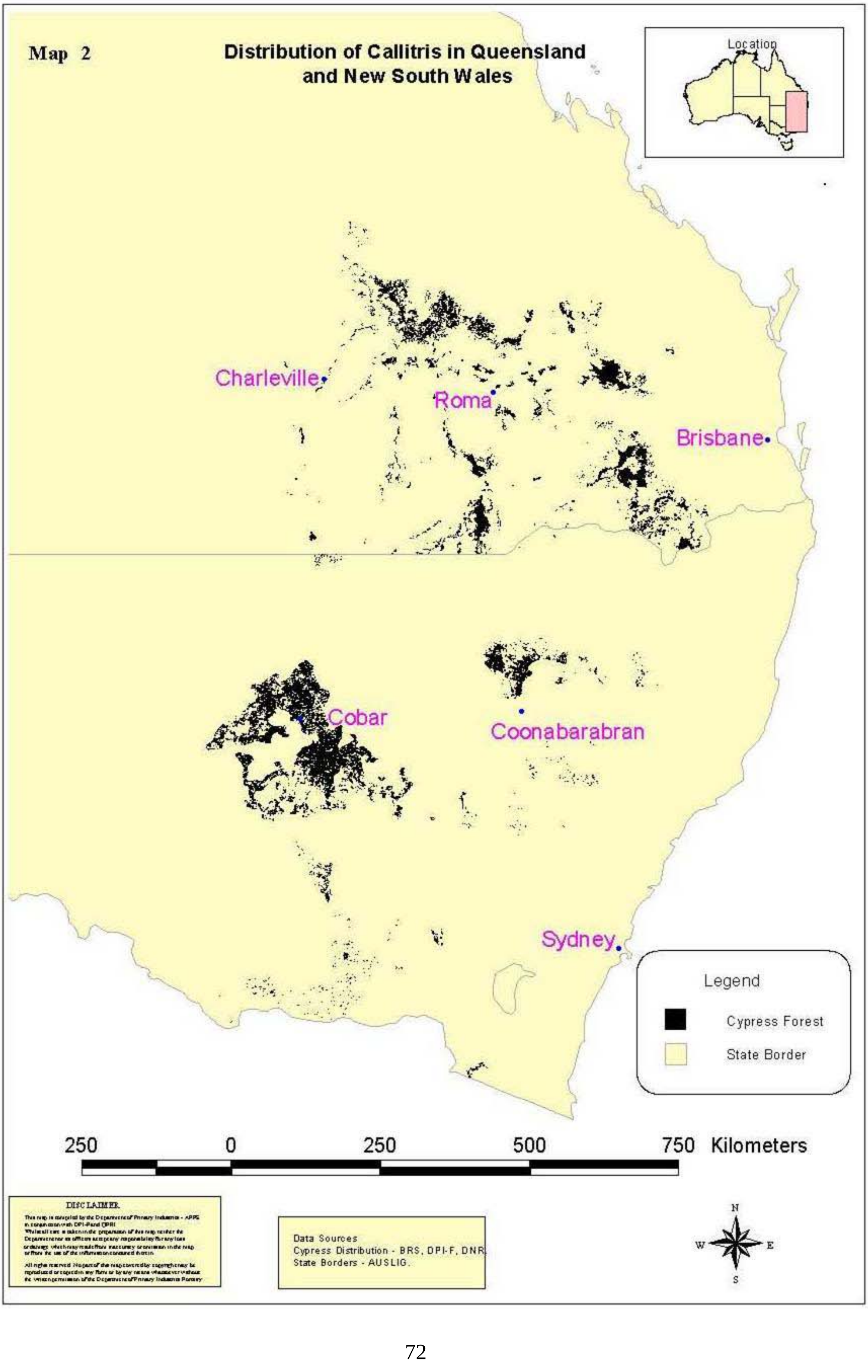
Tree No	LOG VOL	GOS VOL	DGV
211	0.493	0.192	0.131
212	0.380	0.130	0.215
213	0.110	0.053	0.025
214	0.428	0.194	0.131
215	0.427	0.190	0.130
216	1.280	0.484	0.355
217	0.489	0.244	0.182
218	0.702	0.242	0.146
219	0.598	0.250	0.214
220	0.607	0.212	0.103
221	0.222	0.078	0.065
222	0.551	0.250	0.199
223	0.513	0.249	0.177
224	0.561	0.225	0.170
225	0.710	0.286	0.229
226	0.564	0.203	0.141
227	0.315	0.138	0.099
228	0.530	0.236	0.162
229	0.317	0.111	0.089
230	0.618	0.234	0.178
231	0.136	0.055	0.043
232	0.526	0.210	0.119
233	0.723	0.304	0.211
234	0.343	0.156	0.114
235	0.286	0.127	0.058
236	0.356	0.189	0.146
237	0.432	0.149	0.103
238	0.643	0.240	0.180
239	0.667	0.257	0.200
240	0.669	0.241	0.136
Site 8	**15.196**	**6.127**	**4.453**
		40.319	29.300

Site 9

Tree No	LOG VOL	GOS VOL	DGV
241	0.160	0.073	0.046
242	0.195	0.072	0.063
243	0.133	0.042	0.033
244	0.174	0.085	0.060
245	0.188	0.065	0.035
246	0.121	0.032	0.019
247	0.162	0.064	0.044
248	0.139	0.061	0.051
249	0.188	0.072	0.058
250	0.175	0.101	0.077
251	0.138	0.048	0.030
252	0.103	0.037	0.023
253	0.098	0.032	0.029
254	0.080	0.025	0.017
255	0.240	0.095	0.055
256	0.154	0.063	0.050
257	0.196	0.087	0.065
258	0.123	0.019	0.017
259	0.132	0.054	0.048
260	0.182	0.071	0.046
261	0.120	0.053	0.040
262	0.198	0.042	0.036
263	0.212	0.083	0.039
264	0.127	0.038	0.028
265	0.200	0.086	0.061
266	0.185	0.080	0.064
267	0.202	0.081	0.053
268	0.614	0.276	0.189
269	0.254	0.130	0.080
270	0.320	0.123	0.057
Site 9	**5.514**	**2.185**	**1.514**
		39.626	27.450

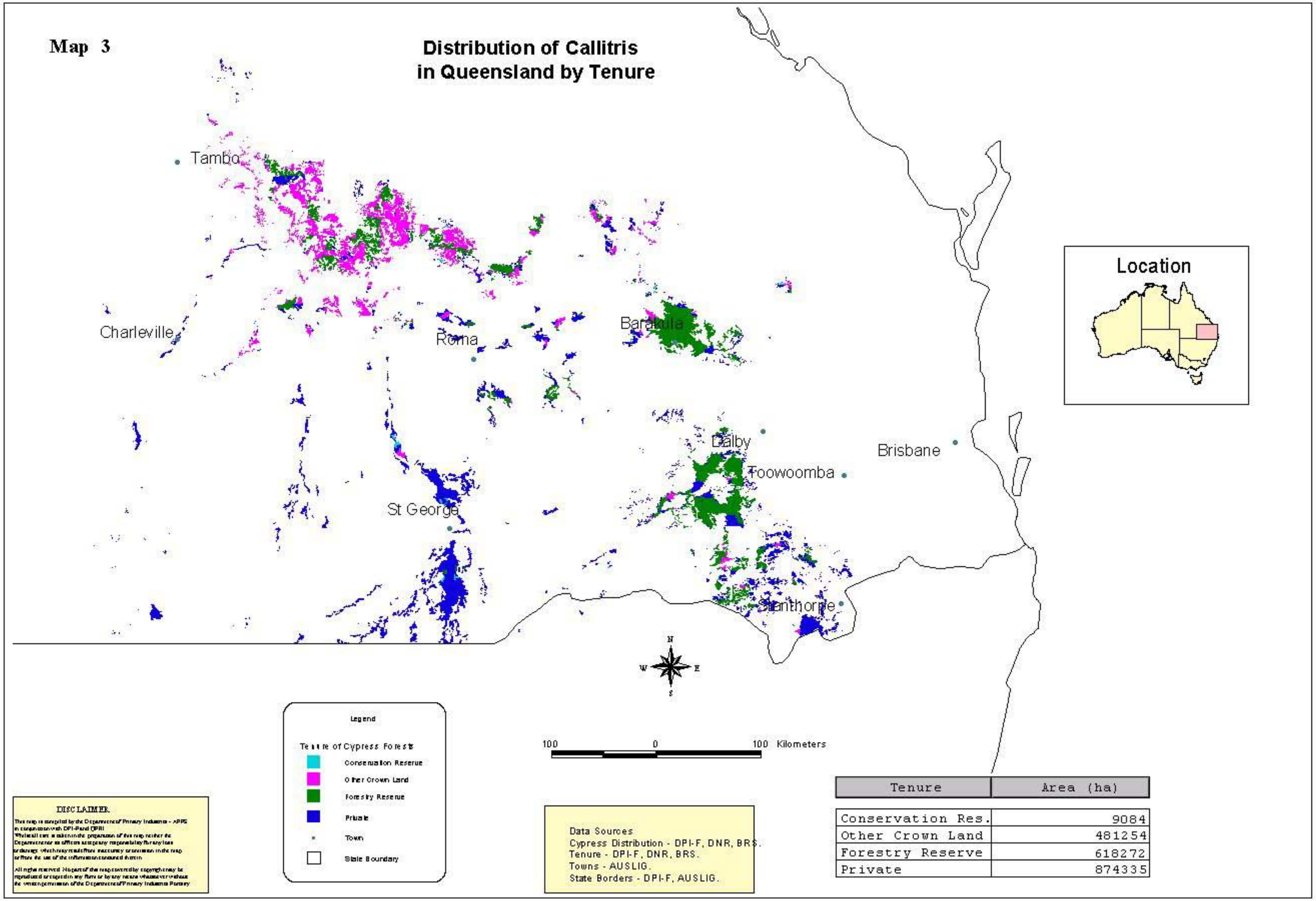
Maps


Map 1
Distribution of Callitris in Queensland and New South Wales
N
W
E
S
500
0
500
1000 Kilometers
Legend
Cypress Forest
State Border
Data Sources
Cypress Distribution - BRS, DPI-F, DNR.
State Borders - AUSLIG.
DISCLAIMER

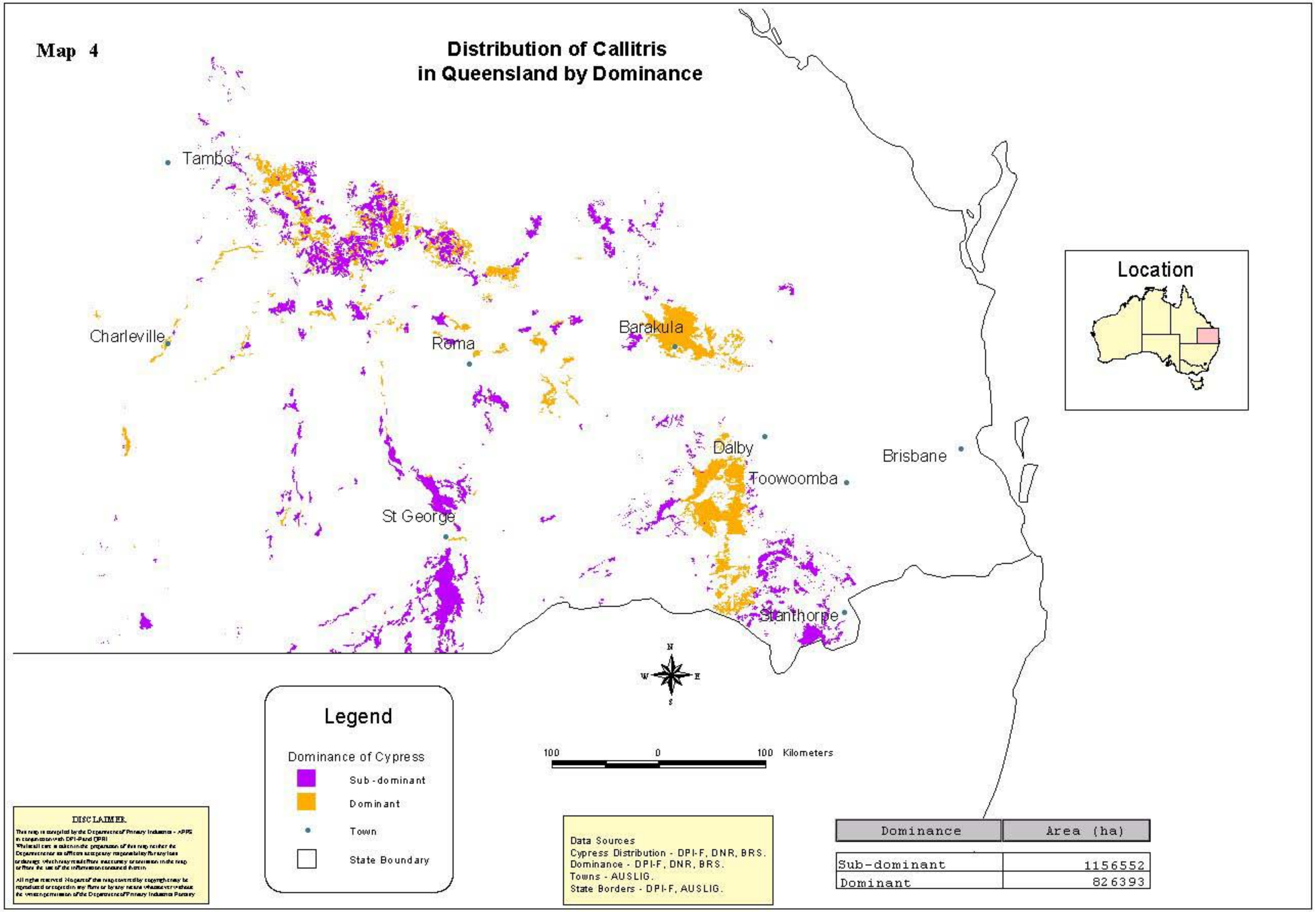

Map 2
Distribution of Callitris in Queensland and New South Wales
Location
Charleville
Roma
Brisbane
Cobar
Coonabarabran
Sydney
Legend
Cypress Forest
State Border
250
0
250
500
750
Kilometers
DISCLAIMER
Data Sources
Cypress Distribution - BRS, DPI-F, DNR
State Borders - AUSLIG.
N
W
E
S

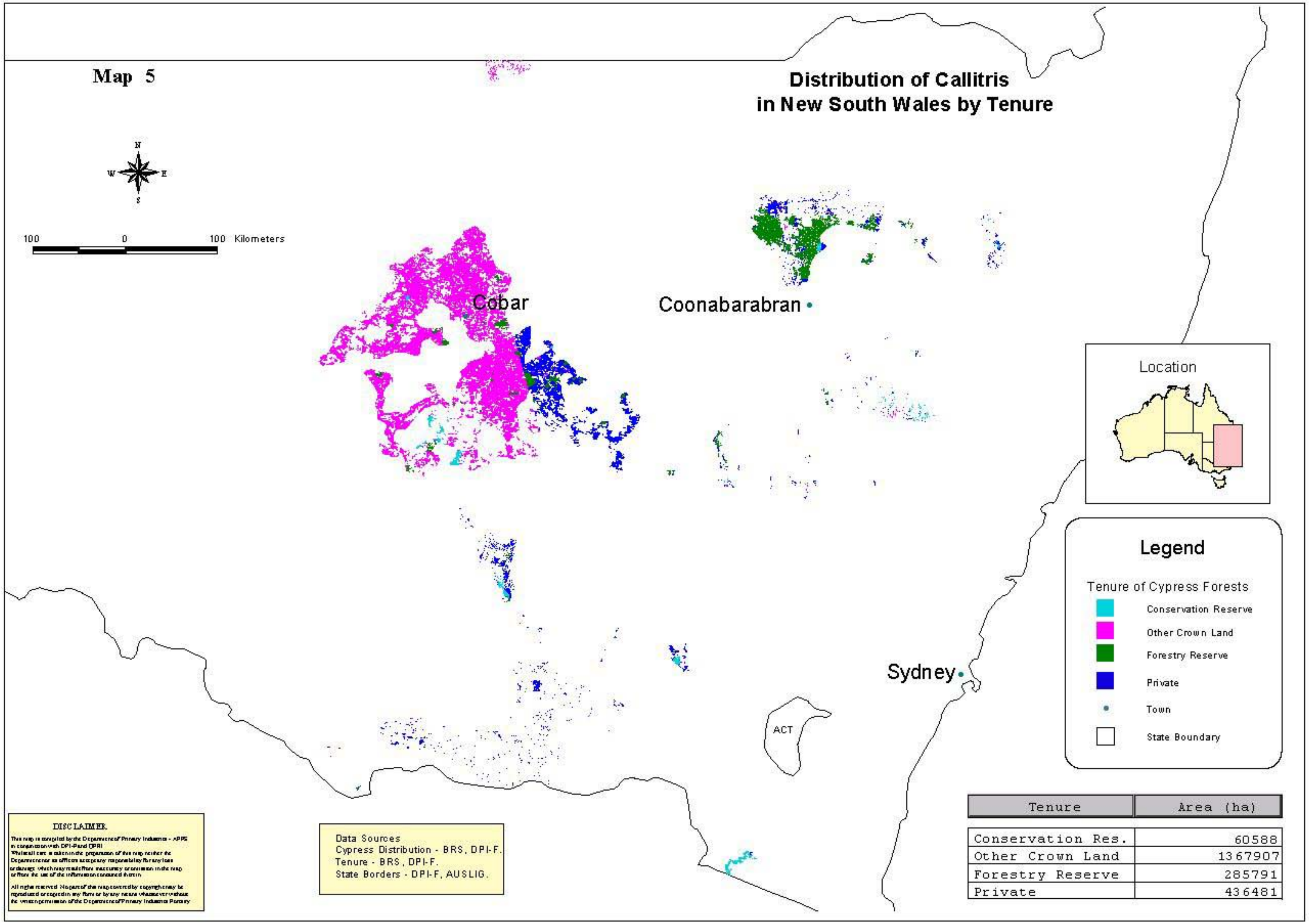
Map 3

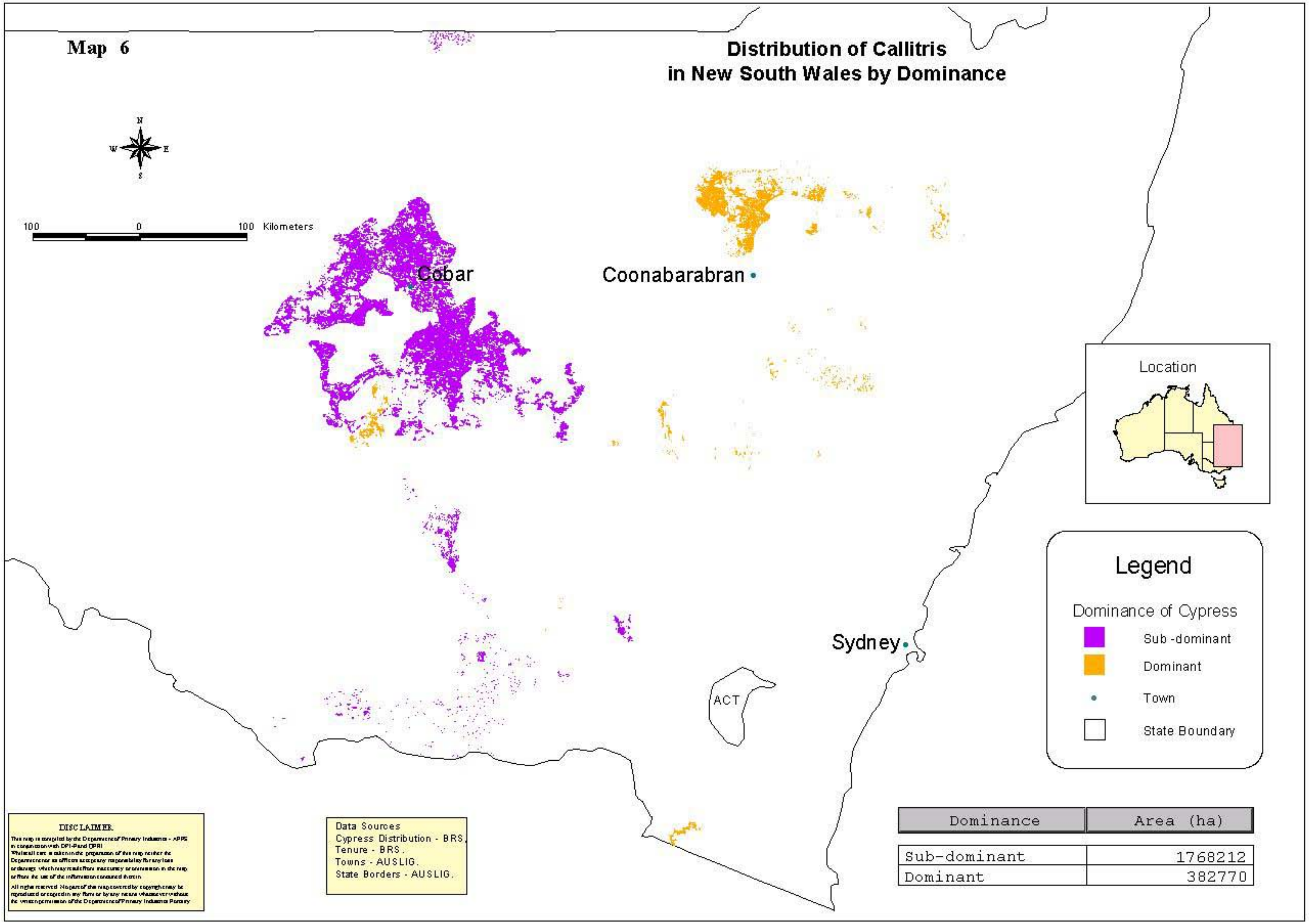
Distribution of Callitris in Queensland by Tenure

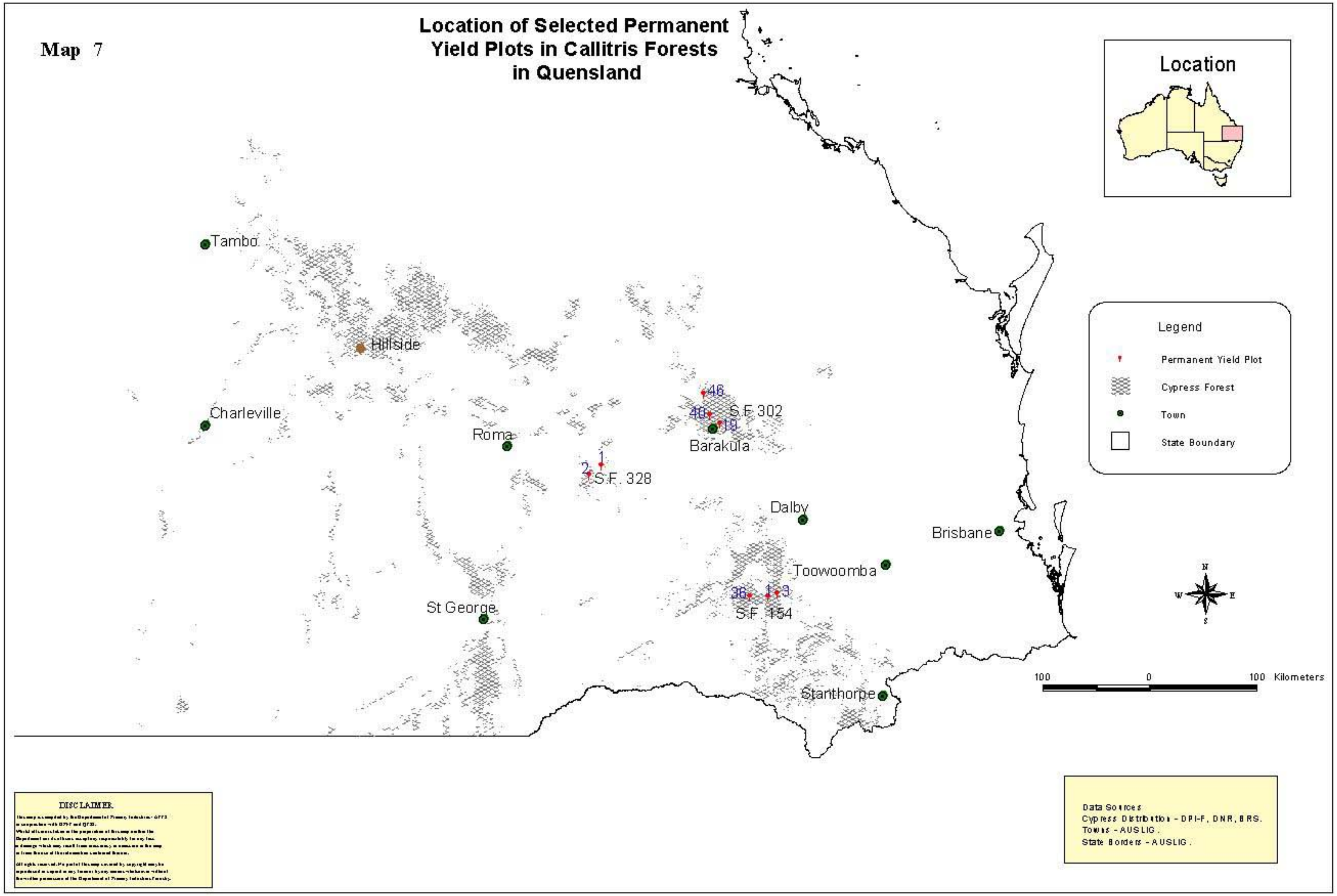


Tenure	Area (ha)
Conservation Res.	9084
Other Crown Land	481254
Forestry Reserve	618272
Private	874335


Map 4
Distribution of Callitris
in Queensland by Dominance
Tambo
Charleville
Roma
Barakula
St George
Dalby
Toowoomba
Brisbane
Stanthorpe
Location
N
W
E
S
100
0
100 Kilometers
Legend
Dominance of Cypress
Sub-dominant
Dominant
Town
State Boundary
DISCLAIMER
Data Sources
Cypress Distribution - DPI-F, DNR, BRS.
Dominance - DPI-F, DNR, BRS.
Towns - AUSLIG.
State Borders - DPI-F, AUSLIG.
Dominance
Area (ha)
Sub-dominant
1156552
Dominant
826393


Map 5
Distribution of Callitris
in New South Wales by Tenure
N
W
E
S
100
0
100 Kilometers
Cobar
Coonabarabran
Sydney
ACT
Location
Legend
Tenure of Cypress Forests
Conservation Reserve
Other Crown Land
Forestry Reserve
Private
Town
State Boundary
Tenure | Area (ha)
Conservation Res. | 60588
Other Crown Land | 1367907
Forestry Reserve | 285791
Private | 436481
Data Sources
Cypress Distribution - BRS, DPI-F.
Tenure - BRS, DPI-F.
State Borders - DPI-F, AUSLIG.
DISCLAIMER


Map 6
Distribution of Callitris
in New South Wales by Dominance
N
W
E
S
100
0
100 Kilometers
Cobar
Coonabarabran
Sydney
ACT
Location
Legend
Dominance of Cypress
Sub -dominant
Dominant
Town
State Boundary
DISCLAIMER
Data Sources
Cypress Distribution - BRS.
Tenure - BRS.
Towns - AUSLIG.
State Borders - AUSLIG.
Dominance
Area (ha)
Sub-dominant
1768212
Dominant
382770


Map 7
Location of Selected Permanent Yield Plots in Callitris Forests in Quensland
Location
Tambo
Hillside
Charleville
Roma
St George
46
40
S.F 302
10
Barakula
2
1
S.F. 328
Dalby
Toowoomba
36
1
3
S.F. 154
Stanthorpe
Brisbane
Legend
Permanent Yield Plot
Cypress Forest
Town
State Boundary
N
W
E
S
100
0
100
Kilometers
DISCLAIMER
Data Sources
Cypress Distribution - DPI-F, DNR, BRS.
Towns - AUSLIG.
State Borders - AUSLIG.

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