REPORT: WHITE CYPRESS (*CALLITRIS GLAUCOPHYLLA*) PLANTATIONS FEASIBILITY SCOPING STUDY

May 2023	Plantation Investment Models

This report was commissioned by the South & Central Queensland Regional Forestry Hub with funding from the Australian Government, Department of Agriculture, Fisheries and Forestry

PLANTATION DEVELOPMENT MODELS

WHITE CYPRESS (*CALLITRIS GLAUCOPHYLLA*) PLANTATIONS FEASIBILITY SCOPING STUDY

Final report

Prepared for

SOUTH + CENTRAL QUEENSLAND REGIONAL FORESTRY HUB

UniSC Australia | Forest Research Institute

Disclaimers

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Acknowledgements

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1. Executive summary

This report has been prepared for the South & Central Regional Forestry Hub (the Hub), who determine the opportunities and barriers for the forestry and wood products sector. This report provides the knowledge and technical support required for the development of a white cypress (*Callitris glaucophylla*) plantation project. A literature review was undertaken and stakeholders were consulted to find information relevant to establish a white cypress plantation on private land in the Hub regions. It is part of a more comprehensive research and development program investigating white cypress plantation potential. The findings from this study were:

- There is 5,114,370 ha of X-class land potentially available for white cypress plantation development. This includes areas that are not suitable for cropping, primarily located in the semi-arid Brigalow Belt, Queensland.
- A review of best-silviculture practices for white cypress plantation development suggests:
  - Seed collection from across the range of the species distribution in Queensland to investigate the best provenance and to facilitate future genetic improvement work.
  - Plantation establishment should occur at the start of the rainy season from December to February. Trees should be planted at a wide spacing of 5 x 5m or 3.3 x 5m (400 – 600 trees/ha).
  - Irrigation water should be applied for the first 2 years following plantation establishment.
- A review of plantation management regimes (post-establishment) suggests:
  - Stocking rates of 400 stems/ha.
  - Thinning should occur at a young age reducing stocking to 260 stems/ha.
  - Weeds and grasses should be controlled to minimise fire risk.
- White cypress has naturally durable timber with good mechanical properties. Heartwood is highly resistant to decay and termite attack, sapwood is resistant to lyctus attack, and both sapwood and heartwood resist impregnation with commercially available preservatives.
- Demand for white cypress timber is greater than the supply available from native forests.
- The current local white cypress processing capacity in Queensland is approximately 112,000 m^3. There are currently 10 existing white cypress sawmills in Queensland. The recent testing of commercial plywood production using spindleless lathes suggests that this capacity could increase.
- Potential uses and markets: White cypress has excellent nail-holding ability, very high tensile strength and is easy to sand and glue which makes it suitable for a wide range of uses for construction and decorative purposes. It could also be potentially used for making essential oils and landscape mulch, bioenergy and plywood. The main market identified for white cypress wood products is domestic, with most of the resources going to Melbourne.
- Key recommendations for the development of a white cypress plantation:
  - Any cypress plantation should be developed on X-class private lands with rainfall ranges between 500 – 700 mm/year in the southern half of bioregion 11 (Brigalow Belt).
  - The cost of establishing one hectare of white cypress plantation was estimated to be $10,550 with costs likely to come down if knowledge, expertise and capacity are developed, including an effective seed supply, improved planting techniques, optimised irrigation and enhanced silvicultural practices (e.g weeding and thinning).
  - White cypress plantations have potential to contribute to economic and environmental values compared to grazing the land. Three scenarios showed the net present values for white cypress plantations over 40 years. Net present values (NPV) were all negative based on assumptions of 40 years rotation, stocking of 260 trees/ha at final harvest, merchantable yield of 61.7 tonnes/ha and stumpage prices ranging from $50 – $120/tonne. This analysis ignored potential income from bioenergy, carbon markets, cattle grazing and environmental credits. When these are included NPV may be positive.

- Sensitivity analysis or bioeconomic analysis regarding plantation development inputs, productivity, potential carbon credits, bioenergy and timber products should be conducted to estimate financial returns from white cypress commercial plantations.
- Policies that give confidence to investors will be needed to facilitate the development of white cypress plantations.

2. Background

Australia's softwood plantation forests covered a total area of 1,028,054 hectares (ha) in 2019 – 2020 (Legg et al., 2021). According to a Forest and Wood Products Australia (FWPA) commissioned report, Australia will be looking to fill a growing gap between supply and demand for sawn softwood timber. To fill the gap, the forestry industry will need to establish 468,000 ha of additional softwood plantations across Australia (FWPA, 2022). However, since 2014/15 there has been a decrease (-0.7%) in Australia's plantation areas (Legg et al., 2021). To meet future increasing softwood demands, significant investment in new plantation areas will be required.

Queensland's softwood plantation estate has about 184,909 ha (data for 2019) and most (about 87%) of the plantation areas are located in Southeast Queensland (DAF, 2021). Plantation investment models, including softwood and hardwood species, are a significant focus of the Hub, which aims to grow the forestry sector to deliver strong financial outcomes, and design and test new models of investment for plantation forests. In the focus area of "Plantation investment models", the Hub's strategy is to assess land availability and identify suitable techniques to contribute to successful plantation investment. The move to new investment models for plantation forests is caused by the transitions away from native forest harvesting across all Australian states. In Queensland, State-owned native timber harvest will cease in Southeast Queensland on 31 December 2024. In the Queensland cypress region, long-term sales permits are now in place until 2037 (previously sawmills only had short-term contracts). Future supply decisions will be informed by outcomes of assessments into sustainable long-term supply options for white cypress timber across Queensland (Native timber action, 2023).

Most commercial softwood plantation species in Southeast and Central Queensland belong to the collective "Southern Pines" which includes *Pinus elliottii* var. *elliottii, Pinus caribaea* var. *hondurensis* and their hybrids. Hoop pine (*Araucaria cunninghamii)* is a native rainforest species grown commercially across 40,000 ha (Neagoe et al., 2022). Currently, there are no commercial white cypress (*Callitris glaucophylla*) plantations in Queensland. Native forests supply about 18% of Queensland's domestically sourced timber and one-third is white cypress, mainly as sawlog and pulp log. Queensland is the largest producer of native cypress sawlogs and timber in Australia (State of Queensland, 2016).

White cypress is a small to medium-sized tree (a height of up to 25 metres and a stem diameter of up to 0.6 metres) and important indigenous softwood in Australia (Lacey, 1973, FWPA, 2021). This species is most common in the temperate and subtropical semi-arid woodlands of eastern Australia and provides the bulk of cypress timber. Particularly, white cypress has natural distribution from central Queensland to Victoria, over most of western New South Wales, with some sporadic outliers in South Australia and southern parts of the Northern Territory and Western Australia. The most extensive growth is in southern inland Queensland and northern New South Wales (Boland et al., 2006, ABARES, 2019).

Recently, the interest in planting white cypress under plantation circumstances has been growing because of the species' suitability as a naturally durable, termite-resistant framing material for housing. White cypress is also used for other construction and furniture with rich colours and features.

Demand for white cypress timber is increasing and the fact that the species grows in lower rainfall areas where land costs are cheaper relative to more coastal areas, suggests there will be less

competition with agriculture (Eco Cottages, 2021). Historically, large volumes of white cypress were harvested from privately owned land, but this has been declining for many years. The prospects of harvesting from private land remain uncertain as a result of extensive land clearing in recent years and uncertainty surrounding vegetation management legislation (Eco Cottages, 2021).

Developing white cypress plantations on private lands is essential to meet Queensland's wood demand and provide long-term productivity and quality for the white cypress industry in Australia. According to the "General guide to the vegetation clearing codes" for landholders throughout Queensland, the category X-class land is not generally regulated by the vegetation management laws (State of Queensland, 2020) and these areas are considered to be available for developing new plantations. The ability to successfully develop a white cypress plantation on private land depends on site ecology, silvicultural practices, social and environmental benefits, potential uses and market opportunities.

This project explores the feasibility to establish white cypress (*Callitris glaucophylla*) plantations on X-class land that is not suitable for agriculture in Queensland. As commercial plantations do not exist, the project team based most of the work captured in this report on findings from the management of native forests of white cypress and stakeholder feedback.

3. Project scope

The project scope was to conduct and deliver the following activities that can provide the technical support required for the development of white cypress plantations in the Hub regions. This project is limited to Queensland local government areas (LGAs) listed in the signed contract between Timber Queensland (TQ) and UniSC. The project team liaised with key business market leaders, and research and development organisations within those LGAs.

Little research has been conducted on white cypress in Queensland over the last 20 years, however, some of the people involved in previous research are still working/known to the research team and were contacted for their input into project milestone delivery. The QDAF database was investigated and over sixty trials were identified that provide information on planting, growth, interaction with pasture and thinning of white cypress. Appropriate project files and reports were examined to distil useful information for this project. A search of the literature was undertaken and relevant literature was sourced.

The following key stakeholders representing business market leaders were consulted and provided useful information for this project:

- Eco Cottages
- Hurford Wholesale
- Vics Timber and Dressing
- Private Forestry Service Queensland (PFSQ)
- QDAF Forest Policy
- Former cypress researchers
- Holdfast Timbers PL/AE Girle & Sons
- Cypress Bark & Mulch Pty Ltd

The questions posed to these stakeholders are summarized in **Appendix 1**.

Other stakeholders in the list provided by the Hub were contacted but no correspondence was received. We also understand that there are now only 10 white cypress processors in Queensland with one of those named in the list from the Hub not being in business.

4. Objectives

The objectives of the Hub cypress plantation feasibility project are to provide basic silvicultural techniques and management practices to establish a novel white cypress plantation in the region.

This project addressed the following detailed objectives:

1. Identify available X-class land that would be suitable and available for cypress plantation development.

2. Describe the best planting and silvicultural practices for white cypress plantation development on private land.

3. Review previous guidelines to assess their applicability to white cypress timber production on private lands.

4. Describe timber properties and quality for the current white cypress logs cut from different silvicultural treatments.

5. Identify the current local white cypress processing capacity.

6. Identify potential uses and markets of white cypress plantations.

7. Estimate inputs and costs for the establishment of white cypress plantations on suitable 'X'-class land.

8. Identify potential social-economic values and environmental benefits from the development of white cypress plantations on X-class land in the Hub regions.

9. Assess the technical skills and knowledge required to establish a white cypress plantation.

5. Methodology

The methods used to address the above objectives are:

Available land: Use spatial mapping, databases/GIS datasets and stakeholder consultation, to identify indicative locations of X-class land available within the native range of white cypress in Queensland for plantation establishment.

Silviculture practices: Use previous studies, available literature and industry experience to describe best-in-practice/most appropriate planting, and silviculture methods for the establishment of white cypress plantations.

Forest management regimes

Review existing forest management regimes with applicability to white cypress plantations, which include stand density, thinning and fire management based on the following references:

- Nicholson, D. (1997). *Managing cypress pine on your property*. State Forests of NSW, Western Division.
- Nicholson, D. (1997). *Managing Cypress Pine for timber production on your property*. State Forests of NSW.
- *Native forest stand management guidelines* – No. 03 (2014) – White Cypress Forests. Private Forestry Service Queensland.
- Wells, P. (2013). *Managing cypress for timber in private native forests*. Australian Forest Grower, 36(4), 41-42.

Wood properties: Review the literature and describe the information available on wood properties and quality (without any silviculture treatment applied versus selected logs with silviculture treatment applied), as a proxy to new white cypress plantations. The description includes termite resistance, shrinkage, density, bushfire resistance, strength group and durability.

Local processing capacity: Identify the current local white cypress processing capacity, including locations and production capacities based on information collected from stakeholders and information from the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES, 2019).

Potential uses and markets: Describe potential uses (wood products, bioenergy and carbon) and markets based on literature, consultations with business market stakeholders and a marketing survey of the Department of Primary Industries (currently QDAF).

Estimate costs of establishing 01 hectares: The estimation is based on the current cost for establishing 01 ha of white cypress plantations on 'X' class land.

Potential socio-economic and environmental benefits: Determine the potential socio-economic and environmental benefits of establishing white cypress plantations on suitable 'X' class land in the Hub regions. This included wood production, ecosystem services, income diversification opportunities, and a source of timber and energy.

Technical skills and knowledge required to establish white cypress plantations: Recommend the technical skills and knowledge required to establish white cypress plantations based on the knowledge gathered.

6. Milestones

The project milestones are shown in **Table 1**.

Table 1. Project milestone deliverables and due dates

Milestone	Deliverable	Due date
1	Detailed project plan, including stakeholder identification and consultation methodology	23/02/2023
2	Draft reports are completed and presented to the Hub Committee at different stages of the project life	30/03/2023
3	A final report is completed and presented to the Hub Committee	26/05/2023

7. Outputs

7.1 Land available for white cypress plantation development

White cypress generally occurs on sandy and loamy soils which are well-drained, particularly along drainage lines and old floodplains (Boland et al., 2006, SCS, 2013, Neumann et al., 2020). The species also occurs in areas with lower slopes and rocky hills (SCS, 2013). The most extensive white cypress native stands occur near Inglewood and between Toowoomba, Dalby, Roma and Wandoan **(Figure 1)** in Queensland (Native timber action plan, 2023).

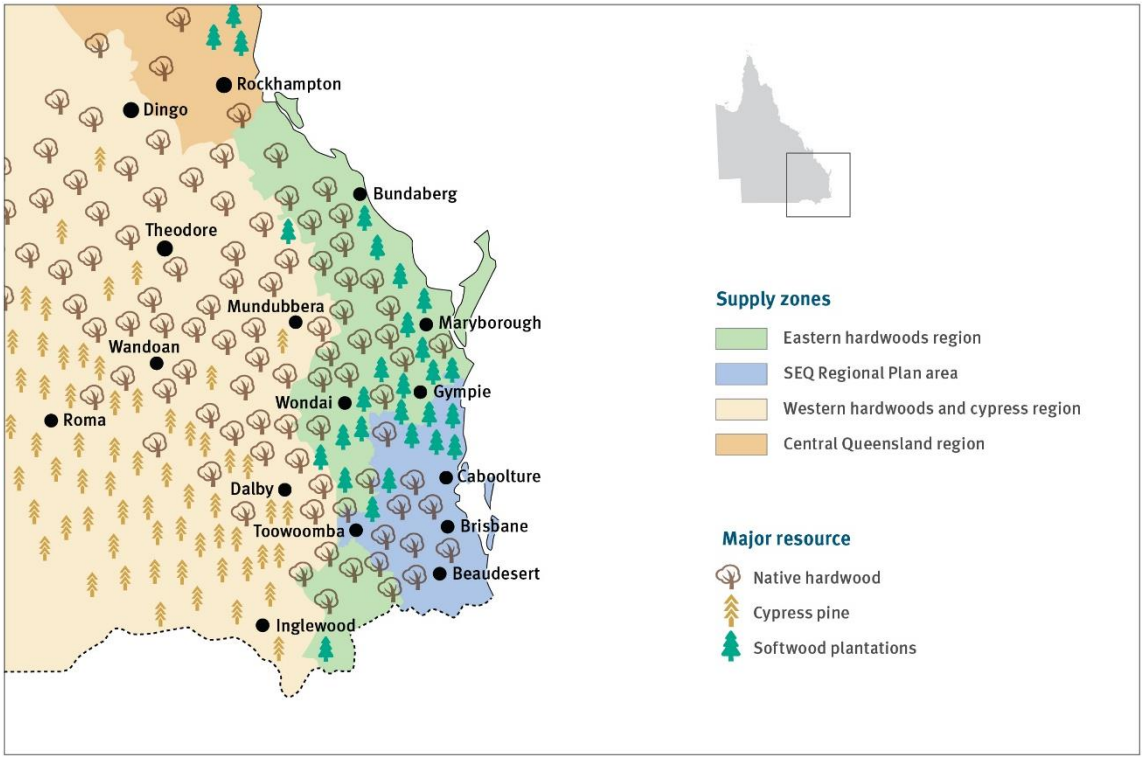

Figure 1. Native forestry in Queensland, revised southern supply zones map. Source: the map created by DAF, available at this link, accessed May 2023.

Identifying key variables affecting plantation development is important to plant white cypress on X-class land. This study identified X-class land in Queensland using a "**General guide to the vegetation clearing codes**" for landholders throughout Queensland and the "**Vegetation management regulated vegetation management map**" from Queensland Globe (RVM category X-class; generally exempt from the Vegetation Management Act). Preliminary analyses from these maps identified approximately **32,605,300** ha of X-class land in Queensland. However, further area elimination was required to identify the available X-class on private land suitable for growing white cypress. Detailed factors are shown below:

Natural distribution: Understanding factors of natural distribution will play a significant role to be successful growth of white cypress in the future. Using bioclimatic data is a key starting point to determine where to establish a plantation when information about the growth of a species outside its natural range is not available (Jovanovic and Booth 2002). Sources used to extract information on the natural distribution of the species were Forest Spatial Data and Queensland Spatial. According to data on **"Biodiversity status of pre-clearing regional ecosystems"** and "**Biodiversity status of 2019 remnant regional ecosystems**", white cypress naturally occurs in 5 of the 13 biogeographic regions in Queensland. **Figure 2** shows Queensland bioregions. We focused our search for X-class land that could be suitable for white cypress within the 5 bioregions where

the species naturally occurs. A total of **22,313,126** ha of X-class land is available within the 5 bioregions where white cypress occurs naturally.

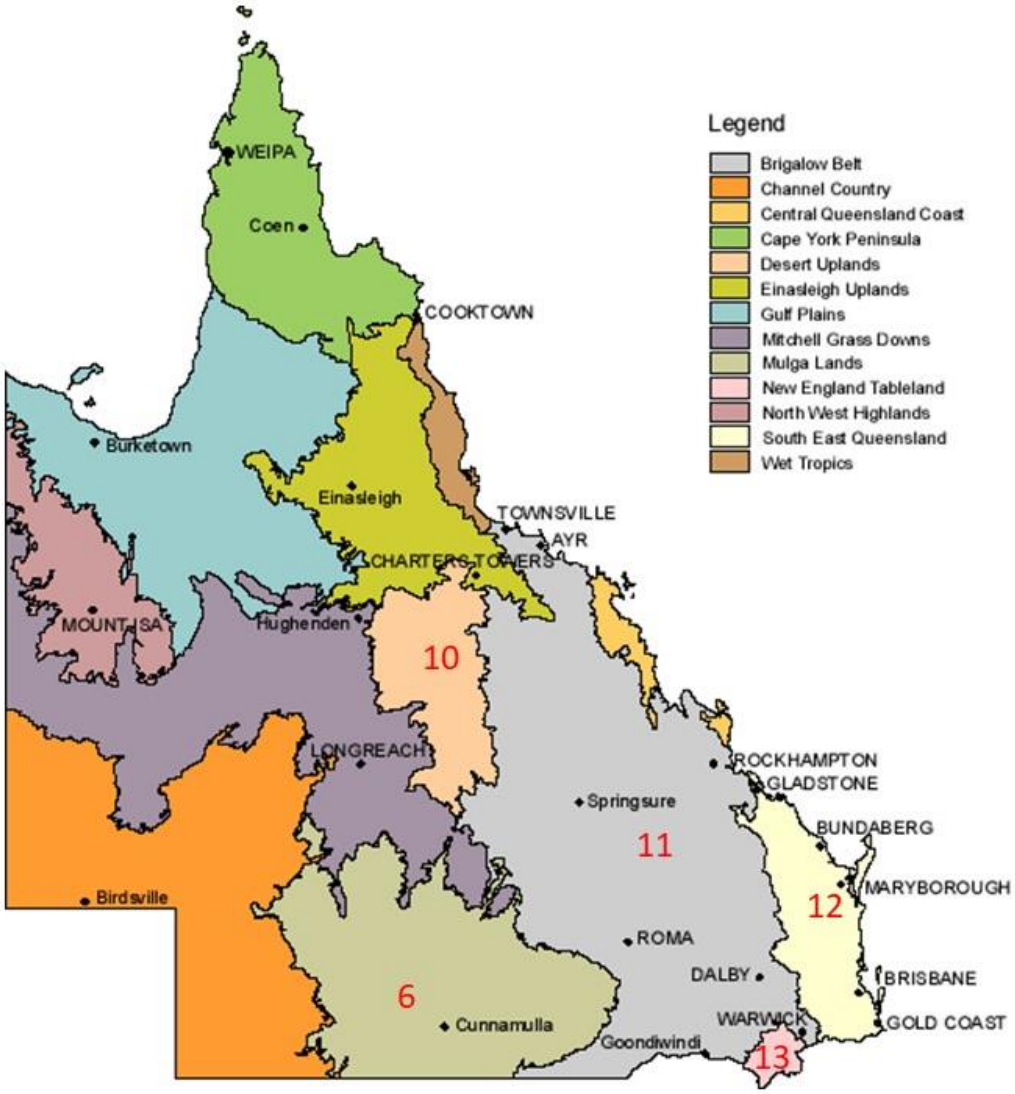

Figure 2. Map of 13 bioregions in Queensland. The five bioregions that cover the white cypress native distribution range are numbered and include Mulga Lands (bioregion number 6), Desert Uplands (bioregion number 10), Brigalow Belt (bioregion 11), Southeast Queensland (bioregion number 12) and New England Table Land (bioregion number 13). (This figure is adapted from the "**Regional ecosystem descriptions**" map, Queensland Government, last updated 14 December 2022).

Rainfall: White cypress is known to grow in a dry subtropical to warm temperate climate and it often occurs in the mean annual rainfall (MAR) range between 380 – 760 mm/year in Queensland (Lacey, 1973) and the range of 400 – 900 mm/year in New South Wales (Wells, 2013). Most of the commercially important white cypress native forest areas receive an average annual rainfall between 500 – 700 mm/year (Lacey, 1973). Over the major area of its commercial distribution, the rainfall varies from north to south in Queensland. The maximum rainfall of 760 mm/year for white cypress growth was recorded in the northeastern part of the range and the minimum rainfall of 380 mm/year was recorded in the southwestern part of the white cypress range (Lacey, 1973). Following consultation with researchers who used to work on white cypress (Scott Swift and David Taylor pers comm 2023), the study of Lacey (1973) and industry stakeholder consultation, this project used the

average annual rainfall map between 1991 and 2020 **(Figure 3)** to select X-class land within the 400 – 700 mm of rain per year in Queensland.

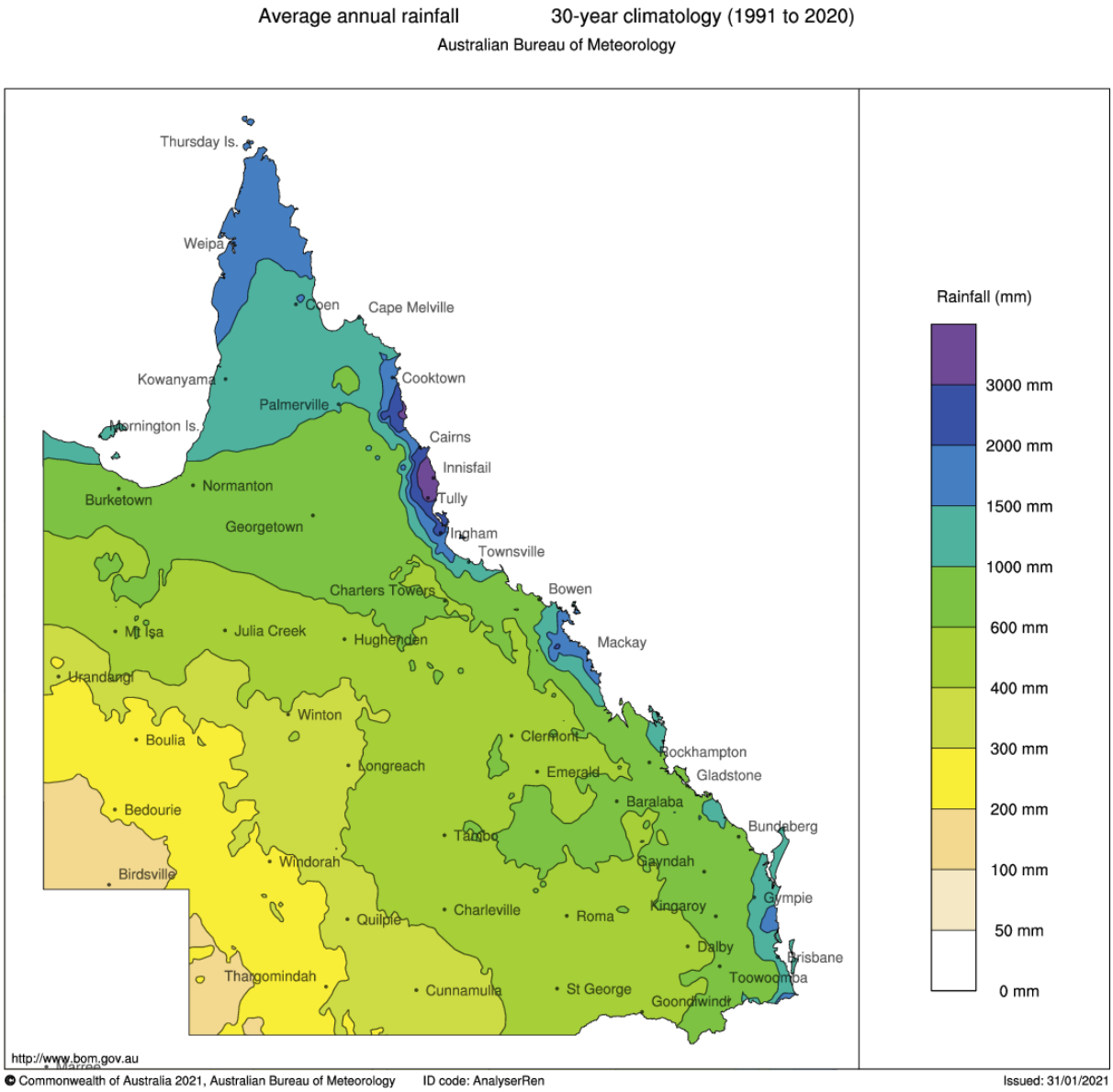

Figure 3. Average annual rainfall map in Queensland. Data records in 30 years (1991-2020) by the Australian Bureau of Meteorology. The map was issued on 31 January 2021. Data accessed by March 2023.

After limiting the total X-class land available for white cypress plantation land by bioregions where white cypress naturally occurs; restraining the area by the northern limit of the species distribution and regions where the average annual rainfall lies between 400 – 700 mm (ideally 500 – 700 mm), further area exclusions were introduced. Areas not considered for white cypress plantation establishment include: areas characterised as high-quality (Queensland agricultural land classes) or priority agricultural land (Regional planning interests - Priority agricultural area), priority living areas (Regional planning interests - Priority living area), and non-Freehold land tenures (Land tenure of Australia 2010 – 11 to 2015 – 16). The resulting X-class footprint available for white cypress plantation development in this area was **5,114,370** ha. This land mainly occurs in Bioregion 11 **(Figure 4)**.

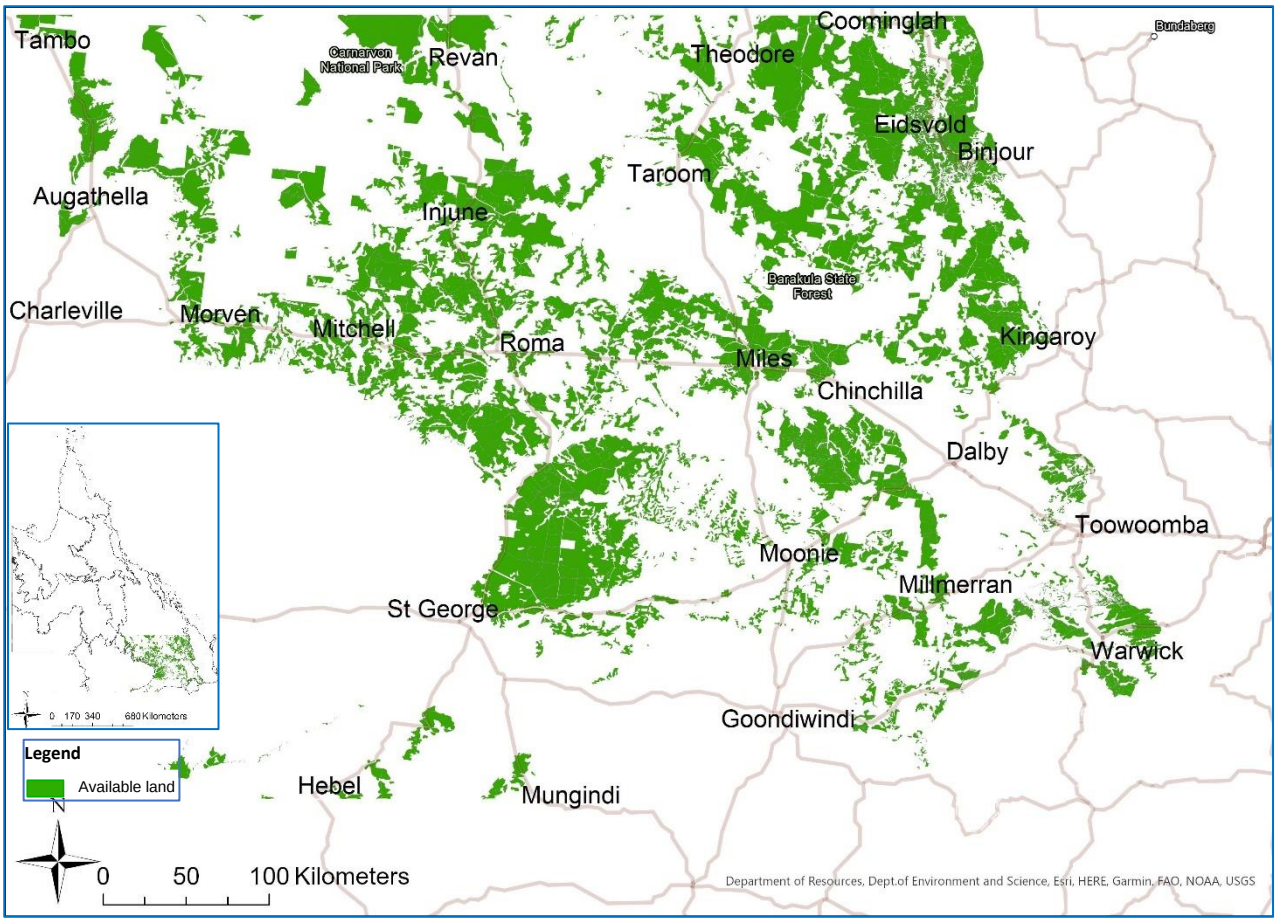

Figure 4. Freehold X-class land was identified as being potentially available for white cypress plantation development in Queensland. The total area is **5,114,370** ha.

Other factors can either be used for more refined mapping in the future (future consideration) or as a tool for white cypress plantation establishment, including soil chemical properties, types, characteristics, and associated eucalypt species.

Soil chemical properties: White cypress is found on a wide range of soil types and has a high level of soil adaptability (Lacey, 1973). This species is particularly insensitive to soil chemical properties and good stand development occurs on very infertile soils and over a wide pH range between 5 – 7.5 and bulk density from 0.68 – 1.68 Mg/m^3 (Lacey, 1973, Thompson and Eldridge, 2005).

Soil types: Soil texture influences white cypress due to its effect on drainage. White cypress often occurs on sites that receive supplementary water from run-off, but it does not grow well in areas where drainage is impeded. Although white cypress is well-adapted to different soil types, opinions from stakeholders suggest that the best white cypress tree growth occurs on deep sands. White cypress naturally occurs on some cracking clays (e.g., on the Darling Downs in Southern Queensland) but these soils are unfavourable for the commercial growth of this species (Lacey, 1973) and stakeholder feedback. Following "**Biodiversity status of pre-clearing regional ecosystems"**, a database was accessed to extract detailed information on soil characteristics of natural forests **(Appendix 2)**, which can be used to identify suitable soil types for white cypress plantation development on X-class land.

Species associations: White cypress is associated with a wide range of dryland eucalypt species (EPA, 2016) depending on each bioregion shown in **Appendix 2** and **Figure 2**. White cypress co-dominates in forest canopies with *Eucalyptus*, *Casuarina* or *Acacia* species over a herbaceous,

shrubby understorey. Some eucalypts commonly associated with white cypress are bloodwoods (*E. bloxsomei* and *E. trachyphloia*), ironbarks (*E. crebra*, *E. melanophloia*, *E. fibrosa* ssp. *nubila*), bimble boxes (*E. populnea*, *E. conica*, *E. microcarpa*), red gums (*E. dealbata*, *E. blakelyi*) and yellow box (*E. melliodora*). Other species are also often found in association with white cypress, including *Corymbia tessellaris*, *Acacia* species, *Angophora* species, and *Allocasuarina* species (NFI, 1997, Boland et al., 2006). Looking for these associated species in the landscape may help identify areas suitable for white cypress plantation establishment.

7.2 Plantation establishment and silviculture practices

Plantation establishment and silvicultural practices involve a range of practices and strategies to increase tree growth, yield and timber supply. Having good silvicultural practices is important as it will allow for the growth of healthy trees and contribute to the future productivity of the forests. However, there are no commercial white cypress plantations in Queensland, with only a few research trials near Inglewood and Gatton (David Taylor 2003, unpublished report). Thus, this section describes the best bet steps for plantations establishment and reviews the current implementation of silvicultural practices based on native forests and how they can adapt to plantation development as follows:

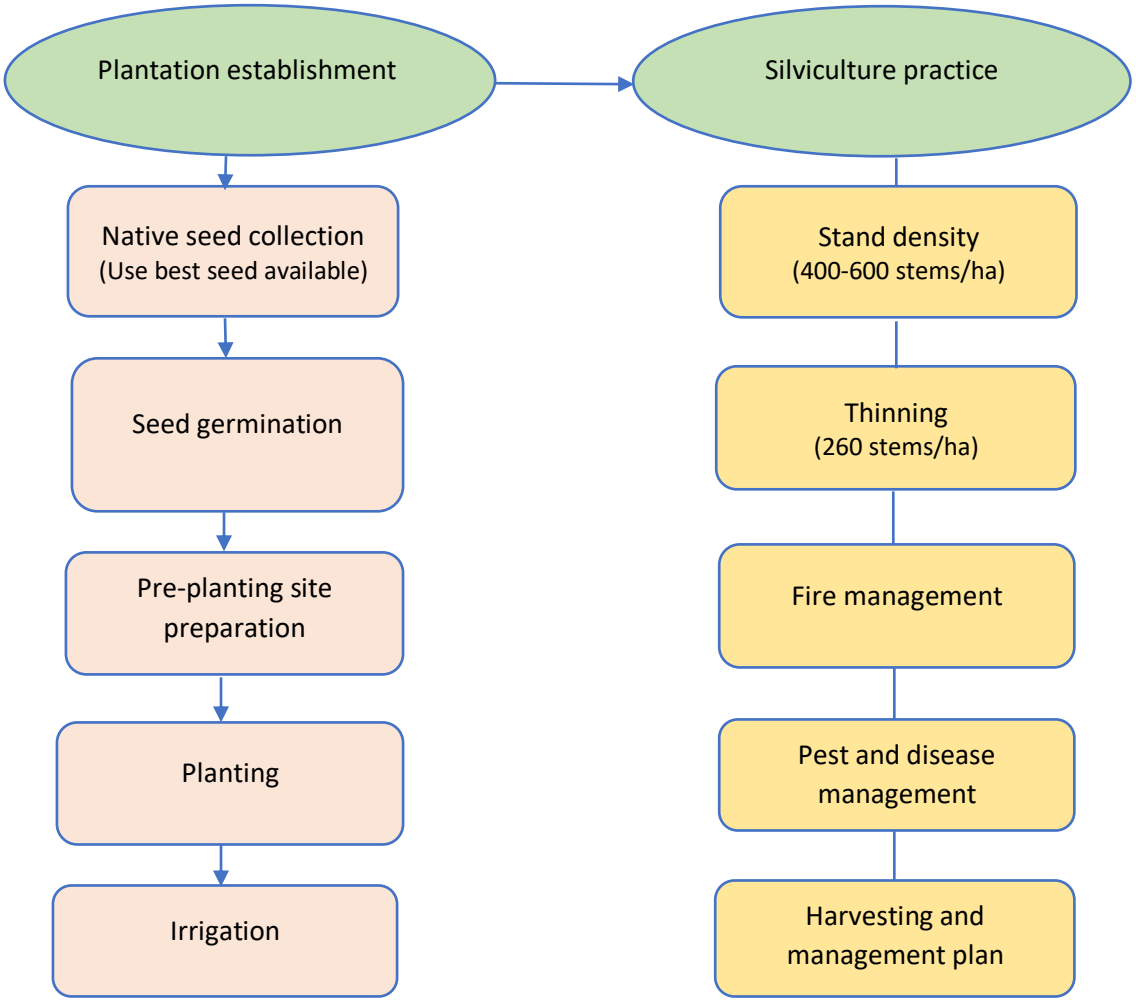

Figure 5. Steps for white cypress plantations establishment and silviculture practices

7.2.1 Plantation establishment

7.2.1.1 Seed collection

Native white cypress reaches its reproductive age at about 6 years. To establish a plantation, seeds should be collected from across the range of the species distribution in Queensland to investigate the best provenances (collecting seeds from 6 – 10 families per provenance) and to facilitate future genetic improvement work. Seed is shed in summer, when the cones dry out, typically between October and January, with a peak in November-December (Lacey, 1973, Thompson and Eldridge, 2005).

Scattered trees or open stands of white cypress regularly produce substantial seed crops. The small, winged seeds are dispersed up to about 60 m in the direction of the prevailing winds and occasionally up to several hundred metres (Forestry Corporation, 2018).

Seedbed conditions are rarely limiting to germination. Maintenance of favourable conditions during a long seedling establishment phase is the main requirement for successful natural regeneration (Forestry Corporation, 2018). This should be considered if white cypress plantations are established.

7.2.1.2 Seed germination and regeneration

Being a conifer, white cypress has both male and female cones, i.e., it is monecious. Young male cones and primordia of the female cones form in November or December and develop through to the following spring. Pollen shed follows, usually between August and October which coincides with the flowering of the female cones.

White cypress is a prolific seeder with between 30,000 and 1 million seeds/ha germinating in the open. Seed germination is highest at 15 – 20˚C and is reduced to zero at 25˚C. Autumn or winter is a suitable time for seed germination due to suitable temperatures and moisture. Following seed fall, white cypress seedlings require adequate soil moisture conditions and protection from fire and grazing to become established (Wells, 2013).

Generally, it is recognised that two consecutive above-average rainfall years are required for successful natural regeneration (Horne, 1990). This suggests that irrigation would be needed for the successful establishment of a white cypress plantation. This was confirmed by several stakeholders who indicated that two years of irrigation would be needed to successfully establish a white cypress plantation.

Based on this information and the team's knowledge of nursery practices, we recommend sowing white cypress seed in late Autumn in 40-cell hyko trays (each cell being 90 cc). Seedlings sown should take approximately 12 -14 weeks to reach a plantable size.

7.2.1.3 Pre-planting site preparation

Prior to planting, weed control and cultivation are required. Strip cultivation just prior to planting will negate the use of pre-plant herbicide application to protect seedlings. Irrigation which appears to be required for white cypress seedling establishment will however promote weed growth. We suggest either mulching (if economically viable) or 2 cultivations be undertaken (separated by several months) to minimise weed growth.

7.2.1.4 Planting

It is suggested that plantation establishment occurs at the start of the rainy season (from December to February in Qld) when there is certainty of follow-up rain, and the winter cold has

passed. This also matches with the raising of the seedlings with the seed being sown in late winter/early spring and the seedlings being ready to plant at the start of the rainy season.

Seedling establishments should use either pogo sticks, grubbers, or planting spades as appropriate. Initial planting spacing should be widely spaced with an associated spacing trial established to allow assessment of growth rates to determine the optimum spacing for the larger plantation estate. Consultations with previous cypress researchers (David Taylor 2003 unpublished report) suggest that an initial spacing of 5 m rows and 3 –5 m along the rows should be considered (400 – 600 trees/ha). A stocking of approximately 260 trees/ha suggests from age 10 onwards in the low rainfall area however this may vary and increase with irrigation. This is supported by finding in native forests (see section 7.2.2).

7.2.1.5 Irrigation and weed control

Following stakeholder feedback (Jeff Girle, Greg Phipps, Vic Gersekowski and Roger Brent pers comm 2023), irrigation water should be applied to the plantation for the first two years following plantation establishment as white cypress seedlings require two wet seasons to become established.

Post-planting weed control might need to be considered, especially under irrigation circumstances and cultivated sites. Post-plant weed control is best applied up to 3 months after planting depending on the weed pressures and species. Hexazinone, clopyralid and simazine can be tested for crop safety at variable rates, with proven efficacy on a range of broadleaf and grassy weeds. At a later age, in a widely spaced white cypress plantation, woody weeds including white cypress wildings might become significant problems. These weeds should be removed either by mechanical tree removal or the use of a woody weed herbicide which could be costly.

7.2.2 Forest management regimes

7.2.2.1 Pest and disease management

Case studies for native forests

Relatively few pests and fungi pathogens affect native white cypress. However, some pests need to be considered when establishing plantations. In native forests, unhealthy trees are sometimes attacked by two borers: the Jewel Beetle (*Diadoxus erethurus*) and Durabilla White Grub (Boland et al., 2006, Ryan et al., 2013). Insect and fungal attacks may exacerbate other injuries. Yellow rot may be prevalent in some areas (Forestry Corporation, 2018).

Adult Cypress Jewel Beetles occur from spring to autumn and larvae and pupae occur all year round. Adult Jewel Beetles breed in stressed, injured and dying trees, freshly fallen branches, and stumps and trash after logging. Larvae feed in the inner bark and outer sapwood resulting in damage to trees. While a few larvae cause minimal damage, many larvae cause extensive damage to the sapwood and the tree can ultimately be ring-barked. A few external signs of jewel beetle infestation can identify by cracking and lifting bark, frass on the trunk or ground in badly infested trees and crown dieback (Ryan et al., 2013).

Durabilla White Grub (Coleoptera: Cerambycidae) is a native longicorn beetle. The larvae of the beetle are typical of the 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. Durabilla White Grub appears to be most active on ‘hard sites’ where the white cypress is associated with narrow leaf red ironbark, i.e., ridges with shallow soils and stone or clay. The adult beetle preferentially lays eggs in suppressed or unhealthy trees, rather than dominant or co-dominant

trees. The damage is seen as tunnels of frass (digested wood) where the wood has been eaten and frass is left behind. The structural properties of the wood are severely impaired (Ryan et al., 2013).

Considerations for plantation development

Most insect pests and diseases occur on stressed, injured, dying trees and unhealthy trees. Thus, plantation management should identify unhealthy trees to prevent pests attack trees and spreading disease to whole plantation areas.

There are no identified native animal threats for white cypress, so this is not considered to be an issue for any potential white cypress plantations. However, cattle can impact the seedling establishment and growth, so these need to be excluded until the trees reach at least 3 – 5 cm in diameter at breast height.

7.2.2.2 Stand density

Case studies for native forests

Where dense stands (up to 1500 trees/ha) of native white cypress regrowth occur, the stand height will grow quickly up to 2 – 6m. Once the site is fully occupied by tree crowns, growth virtually stops. This is called 'stand lock up' and occurs at 30 – 40 years. At lock-up, lower limbs die, and tree growth stops, with the largest stems ranging between 7 – 8 cm in diameter at breast height. The only way to release a locked-up stand is to thin the stand (Wells, 2013, Ryan et al., 2013).

Horne (1990) was able to demonstrate that tree spacing of regeneration (in native forests) at an early age produced greater diameter growth and developed a relationship between stand density and age. Horne's study found that silviculturally treated white cypress forests in central NSW produced 250 merchantable size logs (average 18 cm, diameter over bark) at 33 years after thinning of 7-year-old regrowth white cypress when stockings were 393 stems/ha (nominally 4.9 m x 4.9 m spacing), whereas 3.7 x 3.7 m spacing took 43 years for the trees to reach a merchantable size. The higher stocked treatment took longer or did not reach merchantable tree sizes. In another trial at Strahorn, NSW the 393 and 268 stems/ha had 250 merchantable size logs, 32 years after thinning. An issue with these wider stockings was that the height of the first green limb was 1.2 – 2.1 m and these green limbs were approximately 50% larger than the trees grown under a higher stocking. This would lead to an increase in green knot number and size, in the widely spaced stands. In both of these trials, secondary white cypress regrowth (wildlings) had to be removed to gain an advantage over unthinned blocks.

Considerations for plantation development

A low-density stand with tree spacing 5 m x 5 m to 3.3 m x 5 m (400 to 600 stems/ha) should be planted for white cypress plantations

7.2.2.3 Thinning

Case studies for native forests

Growth rates of native white cypress are generally low compared to other commercial forest types. Thinning is primarily aimed to support growth rates (tree diameter and height increment), improve log quality and provide biomass for compost and biofuels (Eyre et al., 2015). In well-managed native stands, diameter and tree height increments can be reached around 0.2 – 0.5 cm/year and 0.2 – 0.5 m/year, respectively (Ryan et al., 2013). The optimal number of native white

cypress trees on a good quality site should have a maximum of 330 trees/ha in the over 10 cm class size and average spacing of approximately 5.5 m between trees (Ryan et al., 2013). This is similar to the stocking suggested by Horne (1990) for native white cypress stands in NSW.

Currently, native white cypress management in New South Wales involves the older overstorey trees being harvested and the stand left for 3 – 5 years to achieve the best growth potential. Then stands were thinned to a stocking of around 280 stems per hectare (approximately 6 x 6 m) (EPA, 2013). During the thinning operations, the largest and straightest trees are preserved for final harvesting, while non-commercial trees are either felled for products or left as waste (EPA, 2016). Thinning is selective and focuses on retained basal area limits. Lacey (1973) recommended that the maximum stand basal area for average site quality native forest white cypress stand should be around 20 m^2/ha. Thinning native white cypress stands that are less than 20 years old increased height growth to 0.3 m/year, while older stands (e.g. 30 years old) are less responsive to thinning operations.

Considerations for plantation development

Young well-thinned white cypress stands should increase diameter increment, this also leads to sharp taper of the bole and an undesirable log shape for utilization (Lacey (1973). This response of white cypress to thinning at a young age (3 – 5 years old, depending on development) needs to be considered if white cypress plantations are developed.

7.2.3.4 Fire management

Case studies for native forests

White cypress is very fire sensitive and not well adapted to wildfires. Trees of all sizes are usually killed by wildfires and regeneration from seed is often slow (Boland et al., 2006, SCS, 2013, Ryan et al., 2013). In relatively pure white cypress forests, the minimal litter fall of white cypress and shading out of other understorey species reduces fire hazard substantially and fire will not generally carry in these stands (Lacey, 1973).

In some native areas affected by fire, surviving trees may have limited growth for up to 7 years after the fire. The primary factor influencing survival after a fire is the duration and intensity of the fire at the base of the trunk. In the absence of fire, white cypress may develop into very dense stands, with ground cover almost completely excluded (SCS, 2013).

Considerations for plantation development

It is important to be aware of the density of weeds and grasses in white cypress plantations. As the trees are particularly susceptible to fire damage even relatively mild fires may result in tree death at this stage. Thus, reducing weeds and grasses to minimise fire risk is critical for the development of a white cypress plantation estate.

7.2.2.5 Harvesting and management plan

Case studies for native forests

In native white cypress forests, the final harvest of the oldest (largest) class is undertaken when the regeneration class is 4–6 metres high. The regeneration-age class is made up of younger cypress trees beneath the overstory. This provides an opportunity for the regeneration-age class to respond to site release (EPA, 2016). Nicholson, 1997 and Wells (2013) suggest that the best way of

dealing with a native stand of white cypress trees, there are three cyclic stages **(Figure 6)** that should be considered.

Stage 1: Harvest large trees

Commercially harvest the large overstorey trees. When harvesting, ensure enough regeneration 4 – 6 m tall trees remain. Fell to waste any commercially non-viable large trees reduce unwanted secondary regeneration.

Stage 2: Thin to waste

Thin about 3 – 5 years after removing the larger trees. Thin to waste the young 4-6m tall cypress using a heavy-duty brush cutter. Ensure all stumps are cut as close as possible to the ground to avoid vehicle punctures. Retain the largest trees with the best form and growth habits at 6m spacing around 280 trees/ha). Space thinned stands wide enough to grow pasture and stock grazing. Put in a firebreak around thinned stands.

Stage 3: First commercial thinning

Carry out when cypress has a breast height diameter of 14 – 24cm. Fell to waste commercially unviable trees, selecting damaged, less straight, and smallest trees first. Harvest just over half the total number of trees. Leave the straightest and largest trees to grow on, then repeat the same sequence of stages in the next harvesting cycle. Exclude stock (herbivores) to allow regeneration to occur between Stage 3 and Stage 1.

Figure 6. Three-stage cyclic management plan to deal with a native stand of white cypress based on Nicholson, 1997 and Wells (2013).

In stage 1 (above) the average sawlog size is 7 – 8 m long with a log centre diameter of 22 cm over bark. Minimum commercial sawlog sizes are generally 18 cm log centre diameter over bark (Nicholson, 1997) or a diameter of 12 cm under bark (Wells, 2013) and about 2.6 – 3 m in length (Nicholson, 1997, Wells, 2013). Consultations with Holdfast Timbers PL/AE Girle & Sons (Jeffry Girle pers comm 2023) mentioned that log length depends on the size of the tree. Small trees (20 cm over bark) are being cut at 4 m long logs, some bigger trees are cut up to 10 m and these logs may have to be cut a half to fit on the trucks.

Considerations for plantation development

Observations of a few research trials near Inglewood and Gatton showed that those trials grew more slowly than natural white cypress regeneration with growth rates depending on soils and rainfall (David Taylor 2003, unpublished report). During the first eight years, the planted white cypress grew at about 0.5 m/annum. No information is provided on the growth of the nearby native forest. An experiment near Inglewood (640 mm rainfall) compared growth rates of planted white cypress against natural regeneration. At age 25 years, the height and diameter development of natural regeneration was greater than that of the planted white cypress (David Taylor 2003, unpublished report). Further research needs to be conducted as the growth data for these trials was not available.

Outside of Australia, good growth of white cypress plantations has been recorded in the Republic of South Africa, where one plantation was planted with 474 trees/ha. At 38 years old, trees attained a height of 26 m and an average diameter of 38 cm (Lacey, 1973). Note: we would expect overseas plantations to grow more quickly than plantations in Queensland with similar rainfall because the trees would be growing without any natural pests or diseases.

Thinning should occurred between 3 – 5 years, retaining the best form trees around 260 trees/ha. Rotation length around 30 – 50 years, depending on tree growth and commercial sawlog size requirements. It is advised that the harvester check suitable sawlog markets with local sawmills or forestry officers prior to sawlog harvesting.

7.3 Wood properties

White cypress is a distinctive native softwood timber species that is naturally resistant to termite and fungal attack due to the presence of extractives (including 1-citronellic acid, guaiol, and eudesmols) in its heartwood (Evans et al., 1997, Heady et al., 2008). This species does not require treatment for termite resistance, therefore there are no recycling or end-of-life limitations with the use and reuse of white cypress (DAF, 2018). It is also considered to be marine borer resistant (Vic Gersekowski pers comm 2023).

White cypress timber has a creamy, white-coloured sapwood with a darker colour heartwood. The characteristics and identification feature white cypress as shown in **Table 2** and durability shown in **Table 3**. **Table 4** shows the general wood properties of the species.

Table 2. General characteristics and wood structure of white cypress. (Source: Standards Australia, 2007).

Wood appearance	Characteristic	Identification feature
	Heartwood	Vary from light to brown, chocolate, mottle or streaky
	Sapwood	Creamy white, distinct from heartwood
	Texture	Very uniform with some figures and numerous knots

Wood appearance	Characteristic	Identification feature
	Grain	Very fine with an even texture and is generally straight. Knots are common
Wood structure	Growth Rings	Indistinct
	Vessels	Absent
	Rays	Indistinct
	Burning splinter test	Burns well leaving a white ash
	Odour	Distinctive and characteristic

Durability class: Heartwood of white cypress is class 1: highly durable, highly resistant to decay and termite attack in-ground or in persistently damp or poorly ventilated situations (DAF, 2018). White cypress timber also has a wide band of sapwood that is resistant to lyctus attack (Australian Timber Wholesales). The service life of naturally durable timbers in different hazard classes for white cypress includes H5 in the ground (25+ years), H3 above ground exposed and H1 protected **(Table 3)**.

Table 3. Naturally durable hazard classes and service life of white cypress. Source: Standards Australia (2007)

Hazard class	Service life	Exposure condition	Biological hazard
H1 – protected	50+	Inside, above ground. Completely protected from the weather, well-ventilated and protected from termites	Lyctid borers
H3 - above ground exposed	45+	Outside above ground such as periodic wetting and leaching, borers and termites	Moderate decay, borers and termites
H5 - in ground	25+	Outside, in-ground contact with or in fresh water. Subject to extreme wetting and leaching and where the critical use requires a higher degree of protection	Very severe decay, borers and termites

However, the sapwood of white cypress is not resistant to termites or rot and is also difficult to apply pressure impregnation treatment when considering the use of white cypress rounds in the soil.

Table 4. General wood properties of white cypress. Sources: Standards Australia (2007), DAF (2018), Neumann et al. (2020) and FWPA (2021).

Properties	Characteristics
Density per standard	Seasoned: 700 kg m^{-3} Unseasoned: 850 kg m^{-3} Approximately 1.5 m^3 of seasoned sawn timber per tonne

Properties	Characteristics
Strength Group	Unseasoned: medium (S5); Seasoned: reasonably low (SD6)
Stress grades	Unseasoned: F11 (structural No.1); F8 (structural No.2); F7 (structural No.3); F5 (structural No.4); F4 (structural No.4) Seasoned: F11 (structural No.1); F11 (structural No.2); F8 (structural No.3); F7 (structural No.4); F5 (structural No.4)
Shrinkage	Tangential: low (2.8%); Radial: medium (2.1%); Unit movement tangential: low (0.28%); Unit movement radial: medium (0.23%)
Joint group	Unseasoned: reasonably high (J3) Seasoned: reasonably high (JD3)
Lyctus susceptibility	Sapwood is not susceptible to lyctus borer attack
Preservation	Sapwood and heartwood are both very resistant to commercial preservative impregnation
Seasoning	Dries quickly although restriction of the drying rate during the early stages is necessary to avoid fine surface checking. Rarely distorts during drying
Fixing	Seasoned timber may require predrilling when hand nailing but machine nailing with shear point nails is satisfactory. Unseasoned timber generally nails well using either method, but predrilling may be necessary when hand nailing close to ends of boards
Gluing	Can be satisfactorily bonded using special techniques, e.g., slightly roughening surfaces and increasing open assemble times
Fire properties	EFH Spread-of-Flame Index: 8.5 EFH Smoke-Developed Index: 3.5 Critical Radiance Flux - Lower: >2.2 and <4.5 Critical Radiance Flux – Higher: ≥4.5 Smoke Development Rate: <750
Bushfire resistance	BAL 12.5 and 19 – Door and window joinery only

White cypress can be satisfactorily machined and turned to smooth surfaces **(Table 5)**. In terms of hardness, white cypress is a firm timber that ranks between a 4 to 6-class scale regarding both indentation and hand tooling. It readily accepts most standard coatings, stains and polishes. Special techniques, such as surface roughening, are required for gluing (DAF, 2018).

Table 5. Mechanical properties of white cypress. Source: Wood solutions

Properties	Unseasoned	Seasoned
Modulus of rupture	71	79
Modulus of elasticity	7.7	9.0

Properties	Unseasoned	Seasoned
Maximum crushing strength	40	53
Impact	9.7	5
Toughness	Low - up to 15 Nm	Low - up to 15 Nm
Hardness	4.6	6.1

In studies of management impacts on white cypress, it was found that intensive prior management of the white cypress native forest produced an increase in both green-off-saw and dried graded recovery over nil or limited forest management. This was partially due to bigger and straighter logs in the managed forests. Some atypical logs were still found, and the variation was not due to past management. The data (an average dried and dressed recovery figure of 82%) suggested that site factors may influence sawn timber recovery from different native forests (Taylor et al., 2005). This needs to be considered when selecting sites to locate cypress plantations.

7.4 Current local white cypress processing capacity

In 2016 – 2017, there were 17 white cypress sawmills in Australia, with around 13 in Queensland and 4 in New South Wales, all located near cypress-managed native forest resources. The mill recovery rate was 43.3% with an average output of 3,736 m^3/mill/year and with sawn wood output of 57,000 m^3/year (Downham et al., 2019).

In 2016 – 2017, 147,000 m^3 of white cypress sawlogs were harvested across Australia, with 110,000 m^3 from Queensland State Forest and 2,000 m^3 from private land in Queensland (Downham et al., 2019, FWPA, 2021). All the resource in New South Wales is accessed from State Forests.

Currently, there are 10 white cypress mills **(Table 6)** operating in Queensland (Vic Gersekowski pers comm, 2023). These sawmills processed approximately 112,000 m^3/year of white cypress (Downham et al., 2019). Some mills are relatively small-scale enterprises, processing a mix of native allocation and privately sourced timber. For example, Holdfast Timbers PL/AEGirle & Sons recently produced rough timber of 1660 m^3/year. This sawmill is capable of processing several times this volume of timber. However, labour shortages were limiting the sawmills' productivity (Jeffry Girle pers comm, 2023). Access to a suitable workforce may be an issue to consider if a white cypress plantation is developed in these regions.

Table 6. White cypress sawmills and stakeholders in Queensland contacted and those contributing to this project.

Sawmill	Location	Contribution to the project
Holdfast Timbers PL/AEGirle & Sons	Yelarbon	X
Injune Cypress	Injune	
Eco Cottages	Cooroy	X
Hurfords Wholesale	Chinchilla	X
Walker Cypress Mill	Cecil, Plains	
Inglewood Saw Mill	Inglewood	
Vics Timber and Dressing	Cecil, Plains	X
Hornick Cypress	Roma	

Sawmill	Location	Contribution to the project
Queensland Cypress Supplies	Mungallala	
Yuleba Cypress Sawmills	Miles	
Womblebank Sawmilling Pty Ltd	Injune	

7.5 Potential use and market

7.5.1 Potential use

White cypress has excellent nail-holding ability, very high tensile strength and is easy to sand and glue which makes it suitable for a wide range of uses (Eco Cottages, 2021). It can be used as sawn timber for construction or decorative purposes (Standards Australia, 2007).

- **Construction uses**: house framing, fascia's, wall panelling, cladding and bargeboards (Wells, 2013, DAF, 2018).
- **Decorative uses**: including quality indoor and outdoor furniture, turnery, joinery, carving, parquetry flooring and linings (Wells, 2013, DAF, 2018).
- **Other common applications:** oyster stakes and jetty piles in low-salinity environments, as well as beehives (FWPA, 2021). Large solid white cypress logs make excellent durable shed poles and rafters. Due to the high durability of the heartwood, round posts and rails from thinnings and split posts from large defective logs can be used as fencing timber (Wells, 2013).
- **Bioenergy:** White cypress makes excellent kindling wood but burns too hot and quickly for use as a normal stove or heater fuel. The processor Vic Gersekowski (pers comm, 2023) mentioned that using biomass boilers would produce bioenergy efficiently. Wood and thinning of white cypress forests offer a substantial energy resource that could be potentially used for bioenergy both on a local and international scale using cogeneration technology (Neumann et al., 2020). Plantation-grown white cypress could offer similar benefits with thinning waste being used in co-generation. Vic Gersekowski (pers comm 2023) commented that he had looked into supplying a boiler with white cypress waste due to its great heat output (85-95 BTU), but the limited supply of biomass resources had quashed the idea (volumes needed for the boiler were not discussed). Having a white cypress plantation, however, could get around this issue and may lead to greater returns for the enterprise.
- **Residue utilisation**: biomass of white cypress is an option for both landscape mulch and fibre for reconstituted wood panel products due to their natural termite resistance, excellent water retaining and reduced water usage (Cypress Mulch). The Cypress Mulch company is located in Ipswich (Queensland) and the Coastal Landscape Supplies company is located on Sunshine Coast (Queensland). They produce many products from white cypress biomass waste, including cypress blend mulch, cypress genuine red bark, cypress outback orange mulch, carbon black mulch, garden chip and sawdust (Aaron Fitzgerald pers comm, 2023). The Cypress Mulch picks up biomass waste by contracting with Queensland timber sawmills and the longest distance to get biomass from a sawmill is around 1000 km (Aaron Fitzgerald pers commm, 2023).
- **Medium-density fibreboard and plywood**: Historically, white cypress residues from sawmills and commercial logging operations in Australia were being used in the manufacture of medium-density fibreboard (MDF) (Evans et al., 1997). Currently, the first commercial production (Wood Central news, 2023) of white cypress plywood has been produced by the DAF Forest Products Innovation team and key industry stakeholders including Big River

Group, Eco Cottages and Vic's Timber. White cypress plywood is considered a breakthrough product that will be used in the construction of Eco Cottage's prefabricated modular homes (Wood Central news, 2023).

- **Essential oil and indigenous use:** White cypress is an important part of Australia's Indigenous culture (BRS, 2008). Traditionally indigenous people pulled the leaves off and heated the leaves to release the oils which they rubbed onto the skin to assist with skin ailments. (Wood Central News, 2023). Leaves from the thinned trees in native forests are used to extract essential oils by the Native Secrets company. When the trees are cut down, leaves are separated from the wood and the oil is extracted on-site over six hours. The oil is then sent to Sydney for refining and bottling (ABC News, 2021).

7.5.2 Potential markets

Construction and building materials: Historically, white cypress was exported to Japan and the United States as high-grade flooring. Some Queensland sawmills exported up to 80% of their production (BRS, 2008). However, currently following consultation with stakeholders, we found most products are sold in the domestic market (Vic Gersekowski, Jeffry Girle, David Taylor and Greg Phipps pers comm, 2023). In 2016 – 2017, around 73% of the 57,000 m^3 of white cypress sawnwood across Australia was sold as green products (green structural, green appearance and green other such as pallets and fencing). The rest was sold as dry structural/appearance grade (Downham et al., 2019). Of this about 90% of the product from Queensland sawmills is sold to the Melbourne market for flooring and decking and 10% is sold locally in Queensland for cladding (Jeffry Girle pers comm, 2023).

Biomass residue: The price in the local market for white cypress biomass waste is estimated at \$80 - \$ 100/m^3 in the year 2023, with the price varying depending on the product (Aaron Fitzgerald pers commm, 2023). The cost of this residue is unknown. Recently, demand for white cypress biomass has increased, with the demand being greater than what the industry can supply (Aaron Fitzgerald pers commm, 2023).

Essential oil: The market for Australian white cypress essential oils includes leaf oil and wood oil, which are sold between \$12.95 – \$769 (prices for May 2023) depending on the type and size of products. The cost paid for the biomass used to produce these essential oils is unknown.

7.6 Cost of establishing one hectare of white cypress plantations

Typical hardwood plantation costs in regions with existing infrastructure and plantations are in the order of AU\$6000-8000/ha on existing land (anonymous feedback from a planting contractor, 2023) in Queensland. Establishing a hardwood plantation in Kingaroy to age four was estimated to be AU\$2080/ha in 2012 with a total cost to year 12 being AU\$2500 (Maraseni et al., 2012). This was estimated when an active plantation program existed in the region. Due to the remote nature of a proposed cypress plantation, we have approximately doubled the current estimated cost for plantation establishment **(Table 7)**. As the plantation estate increases in area, these costs should come down with operational efficiencies, increased knowledge and skilled labour force, etc.

Table 7. Cost estimated for establishing one hectare of white cypress plantations on suitable X-class land in bioregion 11 of Queensland.

Item	Description	Cost/ha
X-class land purchase	1 hectare in bioregion 11	\$2,000-\$14,000

Item	Description	Cost/ha
	(Based on a survey of properties available on Realestate.com, May 2023)	
Site development	Land clearing, roads establishment and fencing	$2,800
Seedlings	Seed collection (multiple provenances)	$100
	Seedlings 500* x 1 ha = 500 @$1.20 each	$600
Plantation establishment	Planting crew, site prep, weed control (12 months)	$6,000
Irrigation systems	Drip and Sprinkler Irrigation Systems (used for 2 years)	$900**
Thin plantation to 260 stems per ha	Age 3-5 depending on development (take out 1 row mechanically)***	$150
Total	**Total estimate of costs excluding land purchase costs**	**$10,550**

** 400 stems/ha are planted. We have allowed 100 seedlings for refills/poor quality seedlings that are not suitable for planting.*
*** Assumes water is available.*
**** Note trials to evaluate white cypress provenance growth, carbon sequestration and water use should be included but are not covered here as they are not standard operational costs of a plantation.*

7.7 Potential socio-economic and environmental benefits of establishing white cypress plantations

Given the positive economic and environmental benefits of white cypress based on previous studies for native forests, white cypress forests and plantations can provide a landholder with many benefits if they are well-managed (Lacey, 1973, Eldridge and Pickard, 1994, Nicholson, 1997, Thompson and Eldridge, 2005, Wells, 2013). These benefits can include:

- Income from the sale of timber
- Increased property value
- Timber products for on-farm use
- Prevention of land degradation
- Dryland salinity control
- Carbon sequestration and bioenergy

This study found that white cypress plantations could be established in areas classified as X-class agricultural land categories C and D. These land types are suitable only for native pasture or not suitable for agricultural uses other than grazing, due to extreme limitations. In these land types, it is often beneficial to establish a forest/plantation for a combination of wood and grazing production and prevention of land degradation (e.g., soil erosion and salinisation) rather than clearing it for crops or pasture (McHenry et al., 2009).

The majority of benefits mentioned here for native forest white cypress would also apply to white cypress plantations allowing plantation owners to realize important environmental benefits. White cypress native forests have significant roles in storing carbon (Thompson and Eldridge, 2005), improving water quality, and reducing soil erosion (McHenry et al., 2009). Woodlands dominated by native white cypress are capable of efficiently storing carbon in both the soil and vegetation. Particularly, in cases where the vegetation displays a varied structural composition (Eldridge and Pickard, 1994, Thompson and Eldridge, 2005). Dense layers of white cypress litter and surface biota also play a crucial role in sequestering soil carbon. Blue-green algae, terrestrial algae, cyanolichens in biological soil crusts, and free-living cyanobacteria residing in the soil below cypress trees can

potentially contribute organic carbon fixed through photosynthesis directly to the soil ecosystem (Beymer and Klopatek, 1991).

A few studies have estimated carbon sequestration for native white cypress in New South Wales and Queensland. The amount of carbon sequestration in white cypress trees was estimated at around 8.7 tonnes of carbon per hectare (tC/ha) which was greater than the carbon stored in the soil on a per-hectare basis (Thompson and Eldridge, 2005). Roxburgh et al. (2006) estimated carbon sequestration of 53 ± 22 tC/ha in Callitris-dominated forests in Southern Queensland. McHenry et al., (2006) found that dense white cypress forests in New South Wales store between 15.5 and 47.5 tC/ha. In another study, a mixed eucalypt – white cypress forest in New South Wales (Yarindury State Forest) carbon sequestration was estimated as 29.4 tC/ha (Neumann et al., 2020).

The study of Neumann et al, (2020) also estimated that the energy available from a white cypress at Yarindury State Forest (NSW) in stands with an estimated age of 70 – 80 years were as follows: bark 20.8 – 21.6 MJ/kg; sapwood 18.3 – 19.2 MJ/kg; heartwood 21.0 – 21.1 MJ/kg. Thus, future research should explore outlooks for emerging markets such as bioenergy and carbon credits of white cypress plantations.

In this study, the base case of financial returns was estimated not considering the cost of X-class land in the Brigalow Belt (bioregion 11). This is due to the broad range of land values seen on Realestate.com (Table 7) and the need to ascertain the price of land that would be suitable for growing cypress relative to other land types in the region (e.g. cropping land). Secondary income streams from carbon credits, bioenergy and grazing are not considered because the estimation of these streams is not available information for plantations. The scenarios outlined here included: Sawlogs are harvested at 40 years; each tree yields 0.3 m^3/tree of merchantable log (using volume equation for natural white cypress provided by DAF Queensland). We assumed an average tree diameter of 25 cm and height of 16 m (based on section 7.2.2.5); stocking at final was assumed to be 260 trees/ha, (following mechanical thinning operations at age 3-4). Routine maintenance is performed at the ages of 10, 20 and 35 years old. Biomass from thinning operations and the plantation management offset some of the costs of these activities. At age 40, the merchantable yield (green weight) of 61.7 tonnes/ha was assumed. In addition there would be biomass that could provide additional income but this cannot be quantified. A range of stumpage prices for the merchantable volume are presented with the $50 being indicative of prices currently paid to DAF Forest Products. It is assumed that inflation is 2% every year (from year one to forty) and the discount rate is 5%. The budget for establishing one hectare of white cypress plantation was AU$10,550/ha (details in Section 7.6). The net present value (NPV) ranges from – AU$6,254.0/ha to –AU$2,428.4/ha for a 40 year rotation depending on stumpage price. If plantation establishment costs were lower (which should occur as a plantation becomes established) the NPV should improve. The NPV would improve if carbon payments (e.g. Australian carbon credit units) and other uses of the biomass were included in the calculation. This was not possible here as the quantities of biomass waste from a white cypress plantation and future carbon prices are both unknown. The NPV shown below also does not take into consideration that the land could also be grazed, which will return an income. This would also improve the NPV of a potential white cypress plantation.

Table 8. Range of financial returns from establishing one hectare white cypress plantation on X-class land in bioregion 11 of Queensland after 40 years of harvesting.

Plantation establishment cost (AU$ /ha)	Stumpage price (AU$/ha)	Yield (tonnes/ha)	Income (AU$/ha)	Net present value (AU$/ha)
10,550	50	61.7	18,621.1	–6,254.0
10,550	80	61.7	29,613.8	–4,614.5
10,550	120	61.7	44,270.7	–2,428.4

Stumpage prices depend on the quality of plantations, well-developed markets for wood purchases, or transfer prices within a company or development of timber markets in the future, making the current NPV for 40 years indicative only.

Establishing white cypress plantations has the potential to contribute economic and environmental values in addition to using land for grazing. However, sensitivity analysis should be conducted for future projects to accurately estimate financial returns from white cypress commercial plantations, considering factors such as plantation development inputs, productivity, potential carbon credits, environmental offset, bioenergy and timber products.

7.8 Recommend technical skills and knowledge required to establish white cypress plantations

Key findings and recommendations based on this project and stakeholder consultations.

Land available for cypress plantation development

- White cypress generally grows best on sandy and well-drained soils. Clay loams with compensating drainage features may also be suitable, but cracking clays are unfavourable for commercial growth.
- A total of 5,114,370 ha of private land was identified that could be used to establish white cypress plantations in Queensland. Establishing white cypress commercial plantations around the main towns including Tambo, Morven, Mitchell, St George, Roma, Injune, Miles, Warwick, Kingaroy, Eidsvold and Theodore would contribute significantly to the local economy and local sawmills in Queensland.

Recommendation 1: X-class private lands with rainfall ranges between 500 – 700 mm/year in the southern half of bioregion 11 is the suggested region for commercial white cypress plantations.

Recommendation 2: Cypress pine plantation trials be established as soon as possible on suitable land in bioregion 11 to guide any future development the species.

Silviculture practices for plantation establishment

- Seed germination is highest at 15 – 20°C and is reduced to zero at 25°C. Seedlings should take approximately 12 – 14 weeks to reach a plantable size.
- Prior to planting, weed control and strip cultivation are required to reduce the use of pre-plant herbicides to protect seedlings.
- Plantation establishment should occur at the start of the rainy season when there is the likely to be follow-up rain.
- Initial spacing of 5 – 6 m rows and 3.3 – 5 m along the rows should be considered (400 – 600 trees/ha) for plantation establishment.
- Cattle can impact the seedling establishment and growth, so they need to be excluded until the trees reach at least 3 – 5 cm in diameter at breast height.
- White cypress can cope with long term droughts once it becomes established.
- Fires should be excluded from white cypress plantations.

Recommendation 1: Native seeds should be collected from multiple provenances to establish plantations and facilitate future genetic improvement work.

Recommendation 2: Irrigation water should be applied to the plantation for the first couple of years following establishment as cypress seedlings require two wet seasons to become established.

Plantation management regimes

- Growth rates of white cypress are generally low compared to other commercial forest types. Thinning is required to support growth rates.
- White cypress is very fire sensitive and not well adapted to wildfires. Reducing weeds and grasses to minimise fire risk is critical for the development of a cypress plantation estate.
- Stressed / sick white cypress can be impacted by boring insects. This can also lead to fungal attacks.

***Recommendation 1*:** Plantations should be managed to ensure the trees maintain fast growth. Woody weed control should be undertaken as needed.

***Recommendation 2*:** Plantation management should identify unhealthy trees to prevent pests attack trees and spreading disease to whole plantation areas. Future research should investigate potential pests and diseases for white cypress plantations.

Recommendation 3: Cypress pine plantations will be slow growing. Native cypress pine forests take up to 40+ years to reach a harvestable size if well-managed. Plantation cypress may take longer (anecdotal observations). This needs to be further investigated.

Recommendation 4: As cypress does not drop its needles, unlike the existing radiata pine plantations, grazing under a cypress plantation is a potential opportunity for a silvopastoral system.

Recommendation 5: Cypress stumps are durable, so extraction following harvesting could assist with plantation management, this may provide an opportunity to develop a renewable biomass market to improve plantation profitability.

Recommendation 6: Exclusion of fires from white cypress plantations will be crucial for success of the enterprise.

White cypress wood properties

- Heartwood of white cypress is class 1: highly durable, highly resistant to decay and termite attack in contact with the ground or in persistently damp or poorly ventilated situations. It is also considered to be marine borer resistant.
- Sapwood is resistant to lyctus attack but not resistant to termites or rot.
- Sapwood and heartwood are both very resistant to commercial preservative impregnation.

Recommendation 1: Site factors may influence sawn recoveries (both green-off-saw and dried graded recoveries) from native forests**.** Research should be undertaken to non-destructively assess the wood properties of different white cypress native forests and any silvicultural experiments in these forests, to evaluate the variation in key wood properties. This may help with selection of sites for white cypress plantation development and guide silvicultural management regimes to improve wood properties of the plantations.

Current local cypress processing capacity

- Local cypress processing capacity in Queensland is approximately 112,000 m^3.
- Currently there are 10 cypress mills operating in Queensland.
- Some mills are relatively small-scale enterprises, processing a mix of native allocation and privately sourced timber.
- Some sawmills have more capacity for harvesting and processing native white cypress.
- Previously 12-month log contracts from the State Government limited the development of the industry. This has now changed to 25-year resource guarantees which means the processors can invest in new equipment and resource development.

Recommendation 1: Policies that give confidence to investors will be needed to facilitate the development of white cypress plantations.

Potential use and market

- White cypress has excellent nail holding ability, very high tensile strength and is easy to sand and glue which makes it suitable for a wide range of uses for construction and decoration.
- Round posts and rails from thinnings and split posts from large defective logs can be used as fencing timber.
- White cypress can be used to make essential oils.
- The main market identified for cypress wood products are domestic with most of the resource going to Melbourne as flooring or decking.
- The retail price of cypress biomass in the local market is \$80 - \$ 100/m^3.
- A market is developing with white cypress essential oil products.

Recommendation 1: With a guaranteed supply, white cypress residue could be used to power boilers/coal fired power stations using cogeneration technology. This should be investigated.

Recommendation 2: Cypress biomass residues can be used for landscape mulch and fibre, manufacture of medium density fibreboard. Options to utilise thinnings from white cypress plantations for these products should be investigated.

Recommendation 3: Future research should explore outlooks for emerging markets such as bioenergy, carbon sequestration (carbon credits) and oil supply from white cypress plantations.

Potential socio-economic and environmental benefits of a white cypress plantation

- Many benefits are documented for white cypress in native forests. These benefits would also be applicable to white cypress plantations: income from timber products, carbon credits both in soil and vegetation and bioenergy; improving water quality and reduced soil erosion.
- The dense layers of white cypress litter play a crucial role in sequestering soil carbon.
- In native forests, carbon sequestration varies from 8.7 – 53 tC/ha, depending on age and site. Bioenergy estimated for a white cypress at Yarindury State Forest (NSW): Bark 20.8 – 21.6 MJ/kg; sapwood 18.3 – 19.2 MJ/kg; heartwood 21.0 – 21.1 MJ/kg. Note that the differences in ecological characteristics between native and plantation forests need to be carefully considered when estimating their roles in carbon sequestration and bioenergy.
- The current NPV of a white cypress plantation is negative. This would improve if income from grazing cattle, carbon markets and bioenergy were included in the calculation. This is outside of the scope of the current study.

Recommendation 1: Sensitivity analysis or bioeconomic analysis regarding plantation development inputs, productivity, potential carbon credits, bioenergy and timber products should be conducted to estimate financial returns from white cypress commercial plantations.

Recommendation 2: Future studies should include carbon accounting frameworks that consider carbon stored in both standing trees and harvested wood products. This may help to increase long-term carbon storage and future commercial benefits of white cypress plantations.

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Appendices

Appendix 1. Stakeholder questionnaire

Questions posed to each processor Person…… /
Company……

1 Are there any clear quality differences between native cypress without any silviculture treatment applied versus native cypress with a selective harvest?

2 How does this translate into a potential planting density or mid-rotation thinning?

3. What is the optimal soil type to grow cypress?
    a. Does soil impact log quality/growth rate?
    b. Are soils accessible during wet periods?

4. What does the current supply chain of cypress look like for your business or in your area?
    a. Cut to length vs whole tree
    b. What is the maximum skidding distance?
    c. What is the maximum transport distance?

5 Potentially including your own business, can you identify other active local cypress processing facilities? Location, production capacities, etc.

6. Do you have access to a market for cypress?
    a. Is the demand greater than the supply?
    b. Where is the cypress product sold (domestically/ internationally)?
    c. What type of products are sold?

7 Cypress is known to grow slower than other native commercial species. Do you see this as a problem? Or is the value outweighing the growth rate?

8. Do you believe cypress can be grown in a plantation configuration?
    a. What would optimal plant spacing be?
    b. Is irrigation required?
    c. How does cypress respond to fertiliser?
    d. What would be the most ideal region?

9. Anything else of relevance you think we should know about cypress?

   a. Pest and disease (insects, fungus, mammal, weed)

   b. Coppicing or regrowth

   c. Fire – drought – floods

   d. Residue

Appendix 2. Regional ecosystems with white cypress

Regional ecosystem details for each regional ecosystem identity. Information provided in this table can be utilized to gain insights into natural ranges and soil characteristics associated with the growth of *Callitris glaucophylla* in Queensland. Source: Regional ecosystem descriptions, Queensland Government.

Regional ecosystem ID	Associated species	Soil characteristic
6.3.16	***Callitris glaucophylla,*** *Acacia excelsa, Geijera parviflora, Grevillea striata* and *Acacia aneura*	Occurs on the **upper slopes** and **crests of sand hills** on **alluvial plains**. Soils are **deep**, ***red or yellow earthy sands***
6.3.17	*Corymbia tessellaris, C. clarksoniana, Eucalyptus melanophloia, Angophora melanoxylon* and ***Callitris glaucophylla***	The soils are **deep**, **earthy or siliceous sands** and associated **sandy-surfaced texture** contrast soils
6.3.24	*Eucalyptus populnea, Acacia aneura, Hakea ivoryi, E. melanophloia* and ***Callitris glaucophylla***	Occurs on **shallow sand** deposits (remnants of levees) on **alluvial plains** of major watercourses. **Shallow siliceous sands**, overlying **cracking clays**
6.4.3	*Acacia harpophylla, A. aneura, Alectryon oleifolius* and ***Callitris glaucophylla***	Soils are either **deep**, texture contrast soils with **thin sandy or loamy**, surface horizons over neutral to **alkaline clay** subsoils, or **mosaics of cracking clays** on gilgai microrelief with **loamy red earth**, texture contrast soils or **uniform clays**
6.5.5	*Acacia aneura*, ***Callitris glaucophylla*** and *Geijera parviflora*	The soils are either **deep**, **loamy red earths**, or deep texture contrast soils with a **sandy surface horizon** overlying a **medium clay** subsoil
6.5.17	*Eucalyptus populnea, E. melanophloia*, ***Callitris glaucophylla***, *Corymbia tessellaris* and *Corymbia clarksoniana*	Occurs on **sandy plains** derived from old levee deposits in the West Balonne Plains subregion. **Red to brown sandy loams**
6.5.19	*Eucalyptus melanophloia, Acacia aneura, Angophora melanoxylon, E. chloroclada* and ***Callitris glaucophylla***	Occurs on degraded deposits of **aeolian sands** east of the Warrego River. **Deep**, red to **red-brown loamy sands**
10.5.5c	*Eucalyptus melanophloia, Acacia sericophylla, Archidendropsis basaltica*, *Corymbia plena* and ***Callitris glaucophylla***	Occurs on **loamy red** and **yellow earths** on undulating **sandplains**
11.3.6	*E. populnea, E, crebra, Corymbia dallachiana, E. tereticornis*, ***Callitris glaucophylla***, *Alphitonia excelsa, Lysicarpus angustifolius* and *Petalostigma pubescens*	Soils are usually **deep massive red and yellow** earth with **dark brown loamy** sand to **sandy loam** grading to **light clay textures** or texture contrast soils
11.3.14	*Angophora floribunda, A. leiocarpa, Eucalyptus tereticornis, E. chloroclada Allocasuarina luehmannii*, ***Callitris glaucophylla*** and *C. preissii subsp. verrucosa*	Occurs on Cainozoic **alluvial plains** with **sandy soils**
11.3.18	*Eucalyptus populnea*, ***Callitris glaucophylla***, *Allocasuarina luehmanni, E. crebra, E.*	Occurs on levees, **higher alluvial plains** and terraces associated with **drainage**

Regional ecosystem ID	Associated species	Soil characteristic
	chloroclada, Angophora leiocarpa, *Geijera parviflora, Eremophila mitchellii* and *Alstonia constricta*	**lines**. The soils are mainly **deep**, **uniform red sands**, or deep, texture contrast soils with a sandy, **thick surface horizon** overlying neutral, blocky to massive subsoils
11.3.19	***Callitris glaucophylla**, Corymbia tessellaris, C. clarksoniana, Eucalyptus melanophloia, Angophora melanoxylon, E. populnea* and *Acacia excelsa*	The soils are **deep to very deep**, earthy sands and associated **sandy-surfaced texture** contrast soils and **siliceous sands**
11.3.39	*Eucalyptus melanophloia, E. chloroclada woodland, Angophora floribunda, **Callitris glaucophylla**, E. populnea, E. populnea x E. crebra hybrids* and *E. tereticornis*	Occurs on **flat** to **undulating wide valley** floors on alluvial or colluvial material derived from surrounding dissected **sandstone** ranges, generally with **deep**, **loamy or sandy, duplex soils**
11.4.12	***Callitris glaucophylla**, Acacia excelsa, Eremophila mitchellii, Acacia pendula* and *Geijera parviflora*	Occurs on **eroding edge** of Tertiary **clay plains**
11.5.1	*Eucalyptus crebra, E. populnea, **Callitris glaucophylla**, Angophora leiocarpa, Allocasuarina luehmannii, Melaleuca decora and C. endlicheri*	Occurs on **flat** to **gently undulating plains** formed from weathered sandstones. **Duplex soils** with **sandy surfaces**
11.5.3	*Eucalyptus populnea, E. melanophloia, Corymbia clarksoniana, C. dallachiana, E. cambageana, E. brownie, E. crebra, Eremophila mitchellii, Geijera parviflora, Archidendropsis basaltica, Erythroxylum australe, Cassia brewsteri, Ventilago viminalis, Allocasuarina luehmannii* and ***Callitris glaucophylla***	Occurs on **flat** to **gently undulating plains** formed from Cainozoic sediments. Associated soils are generally **deep texture** contrast with **thick sandy surface horizons** with some **deep red earths**
11.5.4	*Eucalyptus chloroclada, **Callitris glaucophylla**, Angophora leiocarpa, A. floribunda and E. crebra or E. rhombica*	Occurs on Cainozoic **plains** with **deep sandy soils**
11.5.5	*Eucalyptus melanophloia, E. chloroclada, Corymbia tessellaris, E. crebra, Acacia spp., Allocasuarina luehmannii, **Callitris glaucophylla*** and *Eucalyptus populnea*	Occurs on **undulating plains** and **rises formed** on Cainozoic deposits. Associated soils are usually **deep texture** contrast soils, with **thick, sandy surface horizons** overlying **yellow, mottled clay** subsoils
11.5.12	*Corymbia clarksoniana, C. dallachiana, C. lamprophyll, **Callitris glaucophylla**, Corymbia tessellaris, Lysicarpus angustifolius, Acacia leiocalyx* and *Melaleuca nervosa*	Occurs on colluvial **lower slopes** of **Cainozoic sandplains**
11.5.13	*Eucalyptus populnea, E. melanophloia, **Callitris glaucophylla**, Acacia excelsa and A. aneura*	Occurs on **gently undulating plains** formed from unconsolidated Cainozoic deposits. Usually associated with **shallow to moderately deep**, **loamy duplex** soils or

Regional ecosystem ID	Associated species	Soil characteristic
		shallow to moderately deep, uniform, **clay loam** to deep **red earth soils**
11.5.20	*Eucalyptus moluccana or E. microcarpa or E. woollsiana, Allocasuarina luehmannii* and ***Callitris glaucophylla***	Occurs on **flat** to **gently undulating plains** formed from Cainozoic/Quaternary sediments. Soils are mainly **texture contrast** with **sandy surfaces**
11.5.21	*Corymbia bloxsomei,* ***Callitris glaucophylla****, Eucalyptus crebra* and *Angophora leiocarpa*	Occurs on **Deep Cainozoic Sand plains**/ remnant surfaces
11.7.4	*Eucalyptus crebra, E. decorticans, Corymbia trachyphloia, E. tenuipes, C. watsoniana* and ***Callitris glaucophylla***	Occurs on **low hills** and ranges with **shallow soils**
11.7.7	*Corymbia trachyphloia, E. apothalassica, E. sideroxylon, Acacia shirleyi,* ***Callitris glaucophylla****, Acacia spp, Allocasuarina luehmannii* and *Callitris endlicheri*	Occurs on **low hills** and ranges formed from deeply weathered sediments. Soils are usually **shallow (< 30cm deep)** uniform **sands** with **stone** or **rocks** covering much of the ground surface
11.8.5	*Eucalyptus orgadophila, Corymbia erythrophloia, E. melanophloia, E. crebra, Pittosporum angustifolium,* ***Callitris glaucophylla,*** *Casuarina cristata, Alectryon oleifolius, Psydrax odorata* and *Notelaea microcarpa*	Occurs on **undulating plains**, **rises, low hills** or sometimes **flat tablelands** on top of mountains, formed from basalt. Generally soils are **shallow** to **moderately shallow**, often **rocky** or **stony clays**
11.8.9	***Callitris glaucophylla*** and *Callitris baileyi*	Occurs on **hills** formed from Cainozoic **basaltic rocks**
11.10.4	*Acacia shirleyi, Angophora leiocarpa,* ***Callitris glaucophylla****, Eucalyptus apothalassica, Lysicarpus angustifolius, E. exserta, E. fibrosa subsp. nubilis, E. panda, E. tenuipes, Corymbia trachyphloia* and *E. virens*	Occurs on **crests**, **scarps** and **upper slopes** of ranges formed from medium to coarse-grained sediments with **shallow soils**
11.10.6	*Corymbia trachyphloia, Eucalyptus melanophloia and E. chloroclada, Acacia conferta, A. macradenia, Aotus subglauca, Xylomelum cunninghamianum. Calytrix longiflora, Cassinia laevis, Dodonaea boroniifolia, Grevillea floribunda,* ***Callitris glaucophylla*** and *Leucopogon biflorus*	Occurs on **deep red sandy loam**
11.10.7	*Eucalyptus crebra,* ***Callitris glaucophylla****, Angophora leiocarpa* and *Eucalyptus spp*.	Occurs on the **lower slopes** of scarp retreats, associated with dissected **tablelands**. Associated soils are generally **moderately deep, acidic, sandy, yellow earth** and **sandy-surfaced texture** contrast soils formed from medium to coarse-grained sediments

Regional ecosystem ID	Associated species	Soil characteristic
11.10.9	***Callitris glaucophylla***, *Eucalyptus melanophloia, Corymbia clarksoniana, Eucalyptus populnea, C. tessellaris, E. chloroclada* and *Angophora leiocarpa*	Occurs on **deep uniform sandy** and **deep texture** contrast soils on coarse grained sediments
11.10.11	*Eucalyptus populnea, E. melanophloia, E. chloroclada, Eucalyptus moluccana, E. macrocarpa* and ***Callitris glaucophylla***	Occurs on **undulating to rolling hills**. The soils are predominantly **deep texture** contrast soils with **sandy surface horizons** (up to **70 cm deep**), over **strongly alkaline** to **acidic, yellow clayey** subsoils
11.12.6	*Corymbia citriodora, Eucalyptus crebra, E. microcarpa/E. moluccana, Angophora leiocarpa, E. melanophloia, E. tereticornis, C. tessellaris, C. clarksoniana, E. fibrosa, E. suffulgens, E. exserta Acacia spp*. and ***Callitris glaucophylla***	Occurs on **gently undulating lower slopes** of hills formed from Mesozoic to Proterozoic igneous rocks (granite). Associated soils are often **deep texture** contrast with **thin sandy** or **loamy surface** horizons over acid mottled subsoils to **shallow sandy** or **loamy skeletal soils**
12.8.26	*Corymbia trachyphloia, Eucalyptus crebra, Eucalyptus fibrosa subsp. fibrosa, Eucalyptus montivaga, Lophostemon confertus* and ***Callitris glaucophylla***	Occurs on **hills** and **deeply dissected terrain**. The surface varies from **rocky** outcrops to **moderately deep** texture-contrast soils
12.11.8	*Eucalyptus melanophloia, E. crebra, Corymbia erythrophloia, C. tessellaris, C. clarksoniana* and ***Callitris glaucophylla***	Occurs on **Palaeozoic** and older moderately to strongly deformed and **metamorphosed sediments** and **interbedded volcanic**
12.12.7	*Eucalyptus crebra, Corymbia erythrophloia, Eucalyptus exserta, E. tereticornis, C. tessellaris, C. citriodora* subsp. *variegate* and ***Callitris glaucophylla***	Occurs on **Mesozoic** to **Proterozoic igneous rocks**
13.11.4	*Eucalyptus melanophloia, E. dealbata, E. albens* and ***Callitris glaucophylla***	Occurs on **Mesozoic** to **Proterozoic** moderately to strongly deformed and **metamorphosed sediments** and **interbedded volcanic**

Appendix 3. White cypress distribution map from a 2001 presentation by David Taylor (Queensland Government).