GREENWOOD

STRATEGY

POTENTIAL FOR INCREASED PLANTATION PRODUCTIVITY, UTILISATION AND RECOVERY OF HARVESTED PRODUCTS

Report Prepared for the Central West NSW Forestry Hub

Project reference: CWFH002

November 2021

CENTRAL WEST NSW FORESTRY HUB

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GREENWOOD STRATEGY

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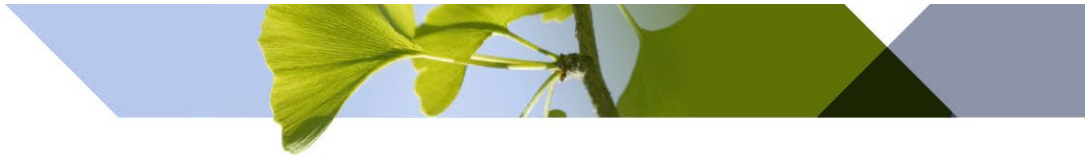


EXECUTIVE SUMMARY

The Central West Forestry Hub has identified a significant gap between available wood fibre and processing capacity in the region. This project has examined opportunities to improve plantation productivity and to improve the utilisation and recovery of harvested fibre in the region in order to deliver potential short, medium and long-term gains.

Opportunities have been identified which have the potential, at the upper limit, to deliver long-term gains of 560,000 m^3/y of additional fibre (representing an increase in MAI of 6m^3/ha/y over a 30 year rotation). When considered in practical terms, there is realistic potential to deliver long-term increases in fibre production between 180,000 and 360,000m^3/y above current sustainable long-term regional harvest levels which are estimated at between 1.3 and 1.5 million m^3/y[1].

The report outlines a process for categorising potential actions and setting priorities for Hub action to focus on delivering these gains. Twelve specific actions have been identified and described.

[1] This estimate is based on multiplying 90,000 hectares by an average regional MAI of between 14 and 17 m^3/ha/y

INTRODUCTION

Greenwood Strategy Solutions Pty Ltd (Greenwood Strategy) has been engaged by the Central West Forestry Hub (the Hub) to undertake this project (CWFH002) to explore the potential for increased plantation productivity, utilisation and recovery of harvested products in the Hub region. This is one of three inter-related projects which the Hub has commissioned Greenwood Strategy to complete. The additional projects are:

CWFH001: Development of a spatial database of plantations in the Central West NSW Forestry Hub.

CWFH003: Plantation capability mapping for the Central West NSW Forestry Hub.

About the Hub

The Hub was established in 2020 with funding under the Commonwealth Government's National Forest Industry Plan (Commonwealth of Australia, 2018).

The Hub is located across parts of the Central and Southern Tablelands of New South Wales (NSW). The majority of the region's commercial forests are concentrated in the Oberon Shire, in the central-east, with important outliers located between Bathurst and Lithgow to the east and around Orange in the north of the region. There are also smaller plantation areas scattered throughout the region, including south of the Abercrombie River (refer to Figure 2).

The forest and wood products sector is focused more or less exclusively on plantation grown *Pinus radiata* as the fibre source for wood products manufacturing, with most of that fibre processed at Oberon and, to a lesser extent, Raglan and Burraga .

The Hub's key objectives are to:

- Analyse the constraints that affect the productivity and efficiency of the forestry sector.
- Pinpoint opportunities for future investment in infrastructure and technology, and areas for potential expansion by forest industries.
- Identify and support business cases for the investment in new infrastructure, such as roads, bridges, ports, telecommunications and training facilities, thereby assisting forest service industries better plan their futures.
- Determine the potential for future plantation expansion within appropriate transport distances and near other existing sources of wood and fibre.

Rationale for the project

Processing capacity exceeds available fibre supply

The Hub has identified that wood processing capacity exceeds the fibre growing capacity of the existing plantation estate in the region. The intent of this project is to examine potential for improvements in plantation productivity, as well as recovery and utilisation of harvested fibre, to generate gains in immediate and future fibre

recovery and distribution from the existing estate. Project CWFH003 considers the potential to expand the plantation estate in the region.

The gap between capacity and supply is growing

The gap between processing capacity and supply in the region is considerable. Based on this project, it appears that the problem has been exacerbated over the past ten years, in particular, by a number of specific events, including:

1. Near completion of clear-fell of the mature, smaller-scale privately owned estate in the region to support containerised log exports to China. In many cases this estate has been allowed to regenerate to wildings rather than active re-establishment with quality tree stocks.
2. Clear-fell and re-establishment of the larger-scale privately owned estate over the past decade or so. In some cases it is not certain that this estate will be actively managed for long-rotation structural wood production, as some regional growers have indicated that commercial drivers may warrant shorter rotations in some instances.
3. Competition between regionally based processors for similar log types and sizes, which are reducing in availability. Log purchase specifications overlap between processors, especially in the 18 cm to 25 cm small end diameter (SED) log grades.
4. Historic purchasing behaviour of some regionally based processors, particularly in relation to smaller plantation owners with less commercial negotiation capacity. There have been historic differences[2] in relation to log purchasing behaviour depending on whether the seller is Forestry Corporation of NSW (FCNSW) or a private forest owner.
5. Purchase of fibre by processors located outside the region, over and above the historic export of logs to China. Logs are currently supplied from privately and publicly owned plantations in the region to Visy, in Tumut (under contract) and a small volume of logs is sold to Hayters Timber & Paving preservation plant and sawmill at Werombi, south west of Sydney.

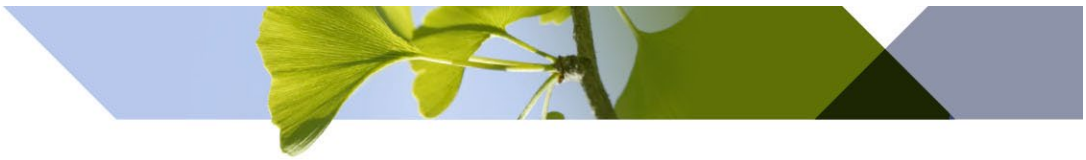
Project methodology

The following broad methodology was developed by Greenwood Strategy, endorsed by the Hub and implemented to deliver the project.

1. One-on-one consultation with critical supply chain actors and other stakeholders.

   Extensive face-to-face and remote consultation with twenty seven key regional stakeholders on the basis of a standardised set of interview guidelines aimed at generating relevant information.

[2] There are a number of historical and commercial reasons for these differences, details of which are beyond the scope of this report



2. In-field observations of operational practice.

   In-field observations of operational practices through the supply chain to the extent facilitated by seasonality, current activities undertaken and Covid 19 restrictions.

3. Identification and categorisation of potential opportunities.

   Based on stakeholder consultation and in-field observations, identifying and categorising key issues and potential opportunities to address productivity, recovery and utilisation of wood fibre in the region.

4. Research and literature review to understand how those opportunities have been addressed elsewhere.

   Research and literature review to identify potential approaches to addressing and realising identified opportunities, including those based on responses to similar challenges in other parts of Australia and the world.

5. Analysis and quantification of potential gains.

   Potential productivity, utilisation and recovery gains were analysed and quantified to estimate the scale of potential opportunities for the region's timber industry.

6. Development of recommendations.

   A detailed set of recommendations was developed based on identification of and priority setting for these opportunities.

INDUSTRY OVERVIEW

Plantation estate

Area assessment

National Plantation Inventory

The Hub area correlates with the Central Tablelands region and part of the Southern Tablelands region of the National Plantation Inventory (NPI). In relation to the Central Tablelands NPI region, the 2018/19 stated area of *P. radiata* was 84,800 ha with 2,800 ha noted as other species (Downham, & Gavran, 2020, p.12).

Spatial database

Subsequent more detailed analysis undertaken for the Hub indicates that the estate comprises an estimated 89,757 ha[3] of plantations comprised almost exclusively of *P. radiata*.

Plantation ownership

There are three broad ownership groups for the region's plantations. These are: large-scale public (government) plantation ownership; medium-scale industrial (private corporate) ownership and small-scale private (individual) ownership. Understanding the ownership breakdown is important in the context of this project because it influences management intent which has further implications for both plantation productivity and the utilisation, recovery and distribution of harvested wood products to the market. Distribution of plantation ownership is presented in Figure 1.

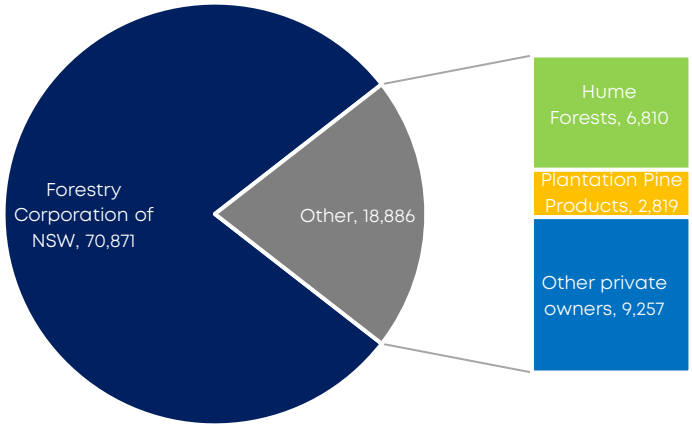
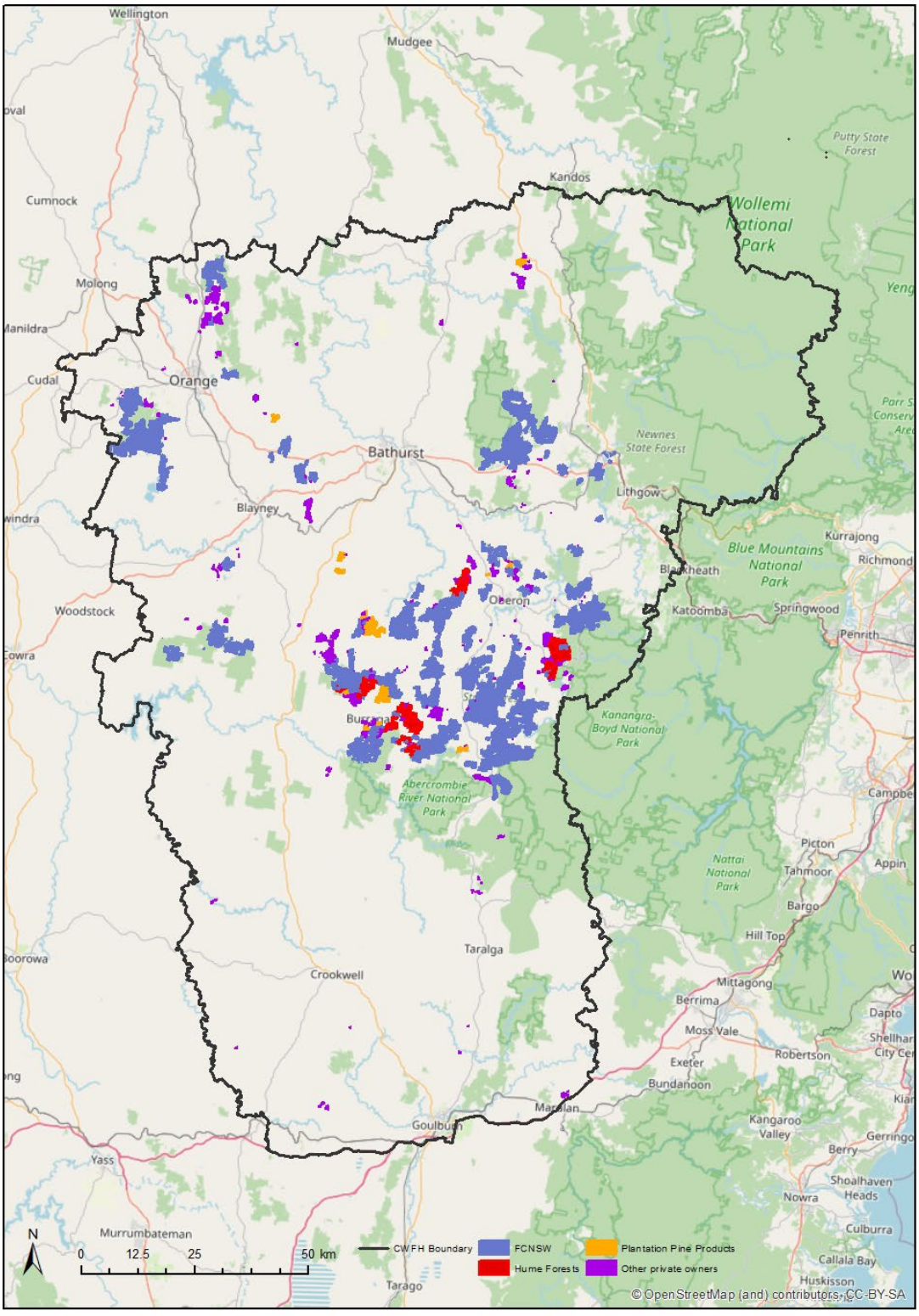


Figure 1: Distribution of plantation ownership by area (ha)[4] for the Central West NSW Forestry Hub (source: CWFH001)

[3] Greenwood Strategy (2021) CWFH001: Development of a spatial database, Report prepared for the Central West Forestry Hub

[4] Note that this refers to mapped area, as described in CWFH001


Wellington
Mudgee
Kandos
Cumnock
Molong
Orange
Cudal
Bathurst
Blayney
Lithgow
Woodstock
Oberon
Taralga
Crookwell
Goulburn
Yass
Murrumbateman
Tarago
Wollemi National Park
Putty State Forest
Newnes State Forest
Blue Mountains National Park
Kanangra-Boyd National Park
Abercrombie River National Park
Nattai National Park
Katoomba
Springwood
Penrith
Richmond
Kurrajong
Picton
Tahmoor
Bargo
Hill Top
Mittagong
Berrima
Moss Vale
Exeter
Bundanoon
Robertson
Kangaroo Valley
Berry
Nowra
Shoalhaven Heads
Culburra
Callala Bay
Huskisson
Dapto
Appin
N
0
12.5
25
50 km
CWFH Boundary
FCNSW
Hume Forests
Plantation Pine Products
Other private owners
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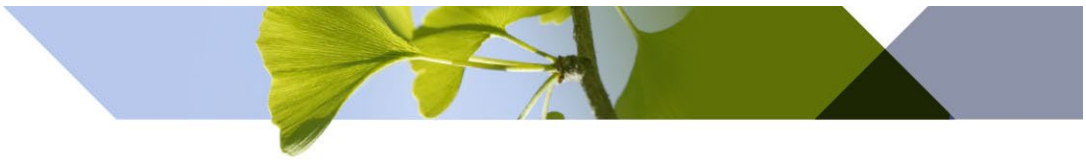


Forestry Corporation of NSW

Forestry Corporation of NSW (FCNSW) is a New South Wales state-owned enterprise which is the major plantation grower in the region. The organisation has, in one form or another, operated in the region since the early twentieth century and commenced establishment of softwood plantations in the Central West from as early as the 1920s. FCNSW manages more than 70,000 ha of publicly owned softwood plantations in region, which have formed the main source of supply for the domestic processing industry over a long period. FCNSW has long-term wood supply commitments with processors in the region. In 2015 these were about 1.02 million m^3/y of sawlogs and pulp logs (FCNSW, 2016). In its forest management plan, FCNSW has identified five fundamentals for maintaining continuous supply from its softwood plantation estate:

- Maintaining or improving productive capacity of the plantation estate
- Fully utilising the available authorised plantation area for growing of plantations where this is economic
- Re-establishing plantations in a timely manner
- Taking advantages in tree breeding where economically viable
- Ensuring optimum log value recovery

Hume Forests

Hume Forests Ltd is an internal management company for investments managed by Global Forest Partners (a large Timber Investment Management Organisation which owns forestry and wood processing assets throughout southern Australia). The Hume Forests estate is comprised predominantly of plantations which were established under private ownership from the late 1960s. The estate has been clear felled and mostly re-established over the past decade. There are small areas of the estate which have been allowed to regenerate wildings rather than by actively replanting. Hume Forests' primary management focus is to generate improved financial returns for the investment fund. Consequently, it is currently considering a range of silvicultural regimes to meet this requirement.

Plantation Pine Products

Over the past two years Plantation Pine Products Pty Ltd, a wholly-owned subsidiary of Borg, has acquired about 3,000 ha of land in the region. Approximately 2,300 ha are existing mature or recently harvested plantations and approximately 700 ha are new plantations. The company's primary motivation for owning and expanding its plantation estate is to secure resource for its medium-density fibreboard panels and particle-board flooring processing facilities at Oberon. Consequently, it is focused on short (14 year) rotations for pulpwood production. Plantation Pine Products has indicated that it is targeting an estate of 25,000 ha in the region, including a mix of established and greenfield plantations. In addition to the 700 ha planted recently, Plantation Pine Products anticipates establishing a further 1,000 ha of greenfield plantations over the next two years.

Other private ownership

The region has a long history of private plantation development extending back to the 1960s. A large proportion of this area was established on ex-pasture land by individual investors, supported by local advisors and initially with low interest Commonwealth Government plantation loans. In many cases the plantations have a poor management history and are of relatively poor quality with respect to productivity, wood quality and tree form. During the past 15 years, much of the private estate has been acquired by other growers and is now owned by either FCNSW, Hume or Plantation Pine Products. However, there remains a small but significant proportion (9,393 ha, representing 10.4% of the mapped area) of the estate owned by individual growers. Most of the private estate has been harvested. Where it remains under ownership by individual growers, an increasingly common second rotation practice appears to be allowing regeneration to wildings and then harvesting the regenerated crop.

Plantation productivity in the region

Overview

In the context of this project, plantation productivity is the amount and quality of commercially marketable fibre that can be grown by a particular estate with a defined area in any particular year. As noted, there is a considerable gap between the region's capacity to process fibre and the ability of the existing plantation estate to supply that capacity. Potential solutions include increasing the plantation area and importing fibre from outside the region. Increasing the amount of wood grown (that is, wood production per hectare) on the existing plantation estate is also an important solution. Strategies and actions to improve plantation productivity typically have a reasonably long timeframe (years or decades) because any intervention undertaken today is dependent for its future success on the growth response of plantations on the site where the intervention is undertaken.

This section considers current productivity of the estate, explores factors which may have historically or may be currently contributing to less than optimal productivity and presents potential opportunities for improving future plantation growth rates and utilisation of the current plantation land.

Current productivity

Plantation growth rates

The plantations of the Central West region have a much greater degree of variability in productivity of *P. radiata* when compared to other regions of NSW and, possibly, other areas of Australia. Comparative mean annual increment (MAI) of *P. radiata* in FCNSW's management areas is summarised in Table 1. FCNSW (2016) notes that its plantations in the Bathurst Management Area are growing at an MAI of between 1.7 and 28.2 m^3/ha/y, with an average of 14.8 m^3/ha/y. It is interesting to note that the Bathurst Management Area has a higher average MAI than the Tumut Management Area and a higher maximum MAI than any other management area on the public plantation estate in New South Wales. However, it also has the lowest minimum MAI.

This suggests that variability between sites, management history and other factors is much greater for the Central West than other regions. However, it also suggests that the potential for productivity improvements in the Central West is considerable, particularly once historic management practices are accounted for.

Table 1: Comparison of mean annual increment for P. radiata in FCNSW plantations

Management Area	MAI (m^3/ha/y)		
	Minimum	Average	Maximum
Bathurst	1.7	14.8	28.2
Bombala	8.9	15.9	26.6
Grafton*	6.7	10.6	12.5
Tumut	5.1	14.7	26.6
Walcha	7.0	18.7	26.0

* Grafton Management Area is in north-eastern New South Wales which is more suited to southern pines due to its sub-tropical location

The Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES; ABARES, 2016) has developed generic regional yield tables for all major plantation species, aligned with the National Plantation Inventory regions. These are presented in Table 2. They are necessarily broad and, in some cases, appear to be somewhat optimistic (for example, an average MAI of 20 m^3/ha/y for *P. radiata* in Western Australia appears to be an over-estimate). However, they do provide a coarse basis for comparison between regions and indicate that the plantations of the Hub region are likely performing at the lower end of productivity for *P. radiata*. The yield tables indicate that the Central West region is one of only two which operate primarily single thin silvicultural regimes and one of three which operate no thin silviculture regimes on a routine basis.

Historical and environmental considerations

Variability in MAI is likely due to a number of factors. Establishment of *P. radiata* plantations in the Central West region begin as early as 1910, with significant expansion events for the public forest estate during the 1920s and then in stages through to the 1980s. From the late-1960s to the mid-1980s there was a significant area of private plantations established– estimated between 15,000 and 20,000 ha. State-owned plantations were established predominantly on former native forest sites until the 1970s, after which plantation establishment was on cleared pasture land acquired for this purpose (Roberts, 2013).

Table 2: Generic regional yield tables for P. radiata across the National Plantation Inventory regions

Region	Plantation productivity at thinning and harvest (m^3/ha)											
	T1		T2		T3		CF		Total			MAI (at harvest)
	Pulp	Sawlog	Pulp	Sawlog	Pulp	Sawlog	Pulp	Sawlog	Pulp	Sawlog	Total	(m^3/ha/y)
Western Australia	80		40	60	60	40	50	270	230	370	600	20
Mount Lofty and Kangaroo Island	110		50	15	20	55	20	350	200	420	620	21
Green Triangle	110		50	15	25	55	20	350	205	420	625	21
Northern Tablelands	70						70	350	140	350	490	16
							168	137	168	137	305	10
Central Tablelands	70	40					70	300	140	340	480	16
							168	137	168	137	305	10
Southern Tablelands	110		40	70			30	220	180	290	470	16
Murray Valley	100		60	60			30	380	190	440	630	21
							220	180	220	180	500	13
Central Victoria	100		60	50			30	300	190	350	540	18
Central Gippsland	80		15	115			170	240	265	355	620	20
East Gippsland/Bombala	110		40	70			30	220	180	290	470	16
Tasmania	100		80	40			40	320	220	360	580	19

The private plantation estate was similarly established on a mix of ex-native forest and ex-pasture sites, of variable site quality. Anecdotally, the quality of site preparation, tree stocks and planting effort on these private sites was highly variable as well (Byrne, pers. comm. 2021). The region is also complex and highly variable with respect to key edaphic factors including geology, rainfall and altitude (Johnson et al, 2008). For example:

- Altitude ranges from 750 m above mean sea level (AMSL) to 1,200 m AMSL.
- Geology is diverse and includes sandstones, shales, siltstones, mudstones, granites and basalts.
- Rainfall varies considerably with altitude and westerly distance from the Great Dividing Range.

Wood products markets

Supply dynamics

Constrained wood supply

The scope of this report specifically excludes consideration of wood flows and wood flow modelling. However, it is important to note and understand that regional fibre production is insufficient to meet existing demand from processing capacity within the region. This fact has implications for aspects of this report, specifically the discussion regarding utilisation of fibre where processors are competing for constrained supply of the same log type.

Extra-regional wood supply

A substantial volume of wood is currently imported to the region, primarily from plantations owned and managed by FCNSW in the Walcha region of northern NSW. Highland Pine Products and Borg are purchasing fibre from the Walcha region[5]. HPP is also purchasing some logs from the Stanthorpe area in Queensland.

Competing specifications

There is competitive tension related to the supply and availability of specific log sizes and grades in the region. In particular, logs in the SED range of 180 mm to 250 mm are in demand from all log buyers and are core to requirements for Highland Pine Products, Australian United Timbers and AAM.

Markets within the region

There are four wood products processors operating within the region which, between them, purchase a full range of log types and sizes up to 57cm large end diameter.

Highland Pine Products, Oberon

Highland Pine Products (HPP) is a 50:50 joint venture between AKD Softwoods and Boral (at the time of preparing this report, Boral has entered into an agreement to sell its timber products business, including part ownership of HPP, to Allied Natural

[5] No definitive volume was provided to the project team. From consultation with the Hub, it is understood that the volume is currently about 160,000 m^3/y. Wood from Walcha is also being transported to Tumut and Tumbarumba.

Wood Enterprises (the Pentarch Group)). The HPP mill located at Oberon, is a significant economic contributor to the region, employing approximately 225 people in manufacturing kiln dried dressed MGP structural timber and treated timber for use primarily in housing construction. The HPP mill has potential capacity of up to 725,000 m^3/y log input running on two shifts. However, it is currently operating on contractual commitments of 525,000 m^3/y with pressure to reduce that due to regional supply constraints (M. Bitzer, 2021, *pers. comm.*).

Borg Group, Oberon

Borg Group's operations include the Australian Panel Products manufacturing facility at Oberon and Plantation Pine Products Pty Ltd (the Group's plantation management company). Australian Panel Products is a leading Australian manufacturer of board products for joinery and structural flooring applications. Its Oberon facilities currently utilise about 1 million tonnes of fibre annually from a range of sources including pine logs from FCNSW (about 600,000 m^3/y), private growers and its own plantations, as well as sawmill woodchip residues and recycled timber. It is likely that the Oberon facilities can process larger volumes in future, subject to fibre availability (C. Berry, 2021 *pers. comm.*).

AAM Investment Group, Raglan

The Raglan sawmill produces a mix of MGP 10 and 12 framing products (28% of output) and fencing materials, comprising predominantly palings with some rails and posts. The mill has about 95,000 m^3/y capacity operating on a single shift. It currently sources 75,000 m^3/y from FCNSW under contract, with the remainder coming from private plantations (C. Neale, 2021, *pers. comm.*).

Australian United Timbers, Burraga

Australian United Timber (AUT) is a timber preservation plant and sawmill located near Burraga. Current processing capacity is 35,000 m^3/y, comprising 20,000 m^3/y from FCNSW on an annually renewed contract and 15,000 m^3/y from private forests. The facility produces a wide range of products including landscaping sleepers, perfect rounds for fence posts and landscaping, hail netting poles for the horticulture industry and other niche products (P. Burke, 2021, pers comm).

Export markets

For the purpose of this report we have considered any purchaser of wood that is located outside the Hub boundary as an export market.

Visy

Visy, with its manufacturing facility located at Tumut, has had an active presence as a wood purchaser in the region for an extended period of time. It currently purchases logs under contract from FCNSW[6] and has purchased reasonably large volumes of fibre from the private forest estate on a casual and contracted basis over the past

[6] The project team understands that the contracted sales from FCNSW to Visy include access to wood from anywhere in the state outside the Tumut/Tumbarumba Region. Therefore it includes wood from Bathurst/Oberon, Bombala and Walcha.

decade. The volume purchased by Visy has varied considerably from year to year up to about 100,000m^3 in any one year.

Hayter

Hayters Timber & Paving preservation plant and sawmill at Werombi, south west of Sydney, purchases a small volume of timber from growers in the region. This is estimated to be less than 5,000m^3/y.

Containerised log exports to China

Containerised log exports were a significant feature of log sales in the Hub region over about 15 years until the recent ban on Australian round log imports by the Chinese Government. Log export operations at Kelso involved truck haulage into centralised yards, with containers packed and transported by rail to Port Botany for sea freight to a range of destinations in mainland China. The most significant aspect of these round log export operations is that they opened up avenues for sale of fibre by the region's smaller private growers at a time where they were struggling to achieve sales of mature plantation resource to local processors. As a consequence of export operations, the majority of mature privately owned resource in the region has now been harvested.

Residues and other volumes

Sawmill residues from HPP, AAM and AUT provide input fibre to the Borg panel plants. Borg also imports wood waste from outside the region, including recycled wood, for use in its MDF and particleboard manufacturing facilities.

FRAMEWORK FOR ANALYSIS

Approach

Productivity can be considered as a measure of how efficiently a forest manager coordinates conversion of inputs into production. As one of the factors influencing profitability, if all other inputs (for example product prices and cost of land) are held constant, productivity gains are the only way to increase net returns for a plantation estate (Moore & Clinton, 2015). This consideration is a single enterprise focus for productivity improvement. However, for the Hub, there are multiple enterprise viability considerations that must be accounted for. Specifically, there is a large wood products manufacturing sector located in and dependent on fibre supply from the Hub's forests. In this broader context, identification and implementation of strategies to improve productivity for the region's plantations is an essential step to ensuring profitability and long-term viability of the entire forest and wood products supply chain in the Central West. A further point is that productivity can incorporate issues related to maximising recovery and utilisation of wood fibre, as these are discrete inputs to production of marketable fibre. This is an important nuance, because it reflects the fact that productivity is not focused simply on producing the maximum amount of fibre but the maximum amount of fibre optimised for the prevailing market conditions. This implies the need for a focus on the ability to grow trees with characteristics to suit a wide range of end uses from the current pulp and woodchip-based products, roundwood and sawn timber, to potentially include veneer, engineered, residues, biofuel and other value-add products. Based on this approach, a framework for analysis of plantation productivity and fibre utilisation and recovery opportunities for the region has been developed utilising a suite of standardised variables applied to each of the three elements (productivity, utilisation and recovery) of the project.

General factors affecting productivity

A range of factors are recognised as influencing plantation productivity (Libby, 2002). Productivity is segmented into biological growth and merchantable volume recovered. The list of factors in Table 3 includes technology and management (human factors), not included in the source reference. That is because, based on stakeholder consultation for this project, these two variables have had a clear impact on the current situation and provide scope for future solutions to addressing the opportunities in the Central West. This demonstrates the difference between biological and merchantable volume.

Analysis framework

A simplified framework, summarised in Table 4, has been adapted for this project to provide a basis for categorising, analysing, quantifying and discussing issues and potential solutions related to productivity, utilisation and recovery.

Table 3: General factors affecting plantation productivity

Factor	Description
Accessibility	Accessibility is not a direct influence on productivity. However, where limits to accessibility are present (e.g. topography or proximity to management), they may restrict the ability to practically and cost-effectively implement required management interventions targeted to improve productivity; for example, thinning, fertilising, in-filling (to maximise area used) or harvesting.
Markets	In a similar way, the presence or absence of markets for particular types of logs can indirectly influence the ability of a forest grower to either cost-effectively or profitably implement specific silvicultural regimes intended to improve productivity; for example early commercial thinning interventions.
Site characteristics	Site characteristics are one of the most important set of factors influencing plantation productivity. These include edaphic (e.g. soil type, depth, drainage, physical and chemical composition), landform (e.g. aspect and topography) with particular influence on micro-climate, weather and climate (e.g. amount and seasonality of rainfall; temperature ranges; frequency of particular types of weather events such as frost, snow and wind; and frequency and nature of climatic events such as drought), historic land use and management (e.g. pre-plantation land-use, fertiliser history and requirements; presence or absence of weeds), and issues associated with the risk of weed competition, browsing and insect pest and disease presence.
Species suitability	Aligned with the issue of site characteristics is the suitability of tree species in relation to the plantation location. In the context of potential impacts of climate change, species selection is becoming perhaps more important as a consideration. This analysis is focused on *P. radiata* as the extant and preferred species for the region's softwood plantation estate.
Tree breeding and genetic improvement	Genetic improvement of target species is a well-established mechanism for generating productivity improvements. *P. radiata* has a long history of tree breeding, in Australia and overseas where established as an exotic plantation species. In Australia, genetic improvement has targeted improved growth rates, wood properties (specifically core wood stiffness for structural wood use), tree form (straightness and prevalence of limbs), capability in more challenging site conditions and resistance to specific pest and disease. These factors influence the ability of the species to produce large volumes of high quality wood for processing particularly in a sawmilling environment.
Quality of tree planting stocks	The quality of tree planting stocks used in establishment of a plantation can have considerable bearing on its productivity. Whether tree planting stocks have been grown in the best or most suitable conditions, how they have been hardened-off, and their transport and storage all impact tree stock quality and subsequent survival, growth and quality of trees in a plantation setting.
Site preparation, design and plantation establishment	Separate to site quality, site preparation, design and establishment practices applied to a plantation can have considerable impact on its subsequent growth, tree quality and yield over a full rotation period.
Silvicultural regimes	The design and application of silvicultural regimes, particularly initial stocking and thinning, is the most significant lever available for forest managers to

	influence plantation productivity once an estate is established. This factor also addresses harvesting, utilisation and recovery.
Technology	Technology has an increasingly important role to play in improving productivity of plantations and recovery and utilisation of fibre; from strategic design, tactical planning through to operational harvest and distribution, on to wood processing. This covers a wide range of potential applications, including remote sensing and mapping, decision support tools and optimising solutions.
Management	Management covers a range of *human factors*, including organisational structures and priorities, communication (within and between supply chain actors), contractual obligations, risk and performance management decision-making frameworks. This factor also addresses harvesting, utilisation and recovery, as well as transport.

Table 4: Approach utilised by this project.

Analysis factor	Description
Site	Variability and issues associated with accessibility and site characteristics.
Biology	Issues related to species suitability, growth and genetics.
Silviculture	Variables related to plantation establishment (including quality of planting stock and site preparation) and silvicultural regimes.
Economics and management	The influence of markets, harvest and haulage, transport networks and distribution systems.
Technology	The role of current and emerging technology through the supply chain, including spatial information systems and optimisers.

Plantation productivity – current state

Site

Variability

As discussed, the Central Tablelands is characterised by considerable variability in site characteristics, including geology and soils, altitude, topography, rainfall and climate. Inclusion of areas of the Southern Tablelands within the Hub boundary adds to variability, although this is more an issue for potential future expansion than for the current estate (given limited plantations south of the Abercrombie River).

Accessibility

There are recognised accessibility issues which may have historically affected productivity in parts of the region.

For example, steep and inaccessible topography may have influenced the quality of establishment and ongoing silvicultural management in public and private plantations in the region. Factors affecting accessibility include topography, soils (particularly in relation to seasonality) and quality of the road network, both within and outside the plantation estate. That noted, accessibility was not raised as a significant issue affecting the growth of plantations and their ability to produce timber. A number of stakeholders did note the impact of accessibility in relation to product recovery and utilisation which is discussed in more detail in the following section.

Site quality

Historically, site quality and characteristics have had a significant influence on productivity and performance of the existing estate. In particular, the contribution of site characteristics to productivity and quality issues for first rotation plantations established on former pasture sites in the region, and south-eastern Australia more generally, is well documented (Birk, 1992; Birk, 1994). For example, deformed stems and poor form of *P. radiata* growing on ex-pasture sites in south-eastern Australia has been termed the Toorour syndrome (Turvey et al, 1993). The syndrome appears to be under genetic control and stimulated by high nitrification in the soil. In summary, ex-pasture sites result in good tree volume growth (e.g. large diameter), with poor form and large branches combined with detrimental effect on structural wood properties (e.g. lower density and poor mechanical properties) and in some cases, poor harvested volume recovery due to tree form.

Of particular interest is the role of trace element depletion (e.g. boron) as well as over-accumulation of nutrients from previous fertilising events which contribute to issues with growth and form. Whether or not these issues are likely to reappear or be manageable for second and subsequent rotations has not been tested on a broad scale. Similarly, these issues are reasonably well understood and have been subject to considerable research. Where plantations have been established on former native forest sites, the influence of site on productivity is less clear, although there is some evidence of specific nutrient deficits in specific soil types, particularly on low fertility, fine textured soils (Turner and Lambert, 2014).

Therefore, while site factors have played an important role in contributing to current plantation productivity, it is not a critical focus area for the Hub in terms of opportunities for improving productivity. The exception is that it will be important to continue to recognise and adapt management interventions (particularly site specific silviculture) related to other factors discussed in this section, in order to address this variability to develop optimum fibre production solutions. The need for this approach is recognised by forest growers in the region (Molkentin, 2021 *pers. comm.*) but it also presents considerable challenges in relation to delivering management efficiencies.

Biology

One stakeholder noted that the Hub region has been considered the 'poor cousin' in relation to the availability and application of improved genetics compared to the south-west slopes. The anecdotal evidence available suggests that this is even more

of an issue for the private than the public estate. There is no empirical evidence available for this project to support the contention that better quality genetics have historically been distributed to other regions in NSW. However, genetics for *P. radiata* have improved considerably over time and more recent plantings and subsequent rotations will almost certainly have benefited. Stakeholders suggested there may be value in considering regionally specific genetics, including progeny trials and establishment of seed orchards, with the ultimate aim to develop a breeding base aligned with local and specific environmental factors.

Silviculture

Site preparation

There has been a considerable area (29,000 ha or 32% of the estate) of plantation establishment across the region over the past decade in the form of subsequent rotations and greenfield establishment. This has followed extensive clearfell operations in the public and private estates. There are three aspects of site preparation which warrant consideration in relation to this establishment program.

Weeds and weed management

Weed control is achieved through application of herbicides (see Figure 3) and is a first consideration. A number of growers and managers noted the challenge of managing weeds pre- and post-establishment, and that more work is required to better understand the impact weeds have on plantation productivity. Especially important is survival at establishment and subsequent growth performance and uptake of nutrients, particularly after fertiliser application.

Weeds directly compete with trees for nitrogen and thereby aggravate nitrogen deficiency (Smethurst & Nambiar, 1989). Early (two and three years) competition between *P. radiata* growing in southeast of South Australia and annual weeds is for nitrogen and water. Increasing width of weed-control strips has little effect on tree water status but increased uptake of nitrogen by trees. Therefore, in general, strip weed control may be a better option than complete weed control (Woods, *et al*, 1992). Tree growth responses to weed control and nitrogen fertiliser are additive (Woods, *et al*, 1992), but interact with site attributes. Application of nitrogen alleviates nitrogen deficiency and weed competition suppressing tree growth. When nitrogen supply is high, intense weed control is unnecessary in plantations beyond two years of age. Competition for nitrogen by weeds seriously aggravates nitrogen deficiency in young *P. radiata* on low-N soils (Woods, *et al*, 1992). Partial weed control may benefit productivity in the long-term because weeds reduce leaching of nitrogen (Smethurst & Nambiar, 1989).

Technological and operational capacity to deliver weed control accurately within a plantation boundary is considered to be adequate in the region. FCNSW noted that the delivery by aerial spraying of herbicides is of an excellent standard. It was noted that the use of herbicides for weed control is a significant area of potential stakeholder conflict, particularly with neighbours concerned about spray drift and

waterway contamination. A current FWPA project is exploring alternative weed control strategies which may be of interest to the Hub[7].

Figure 3: First rotation establishment on an ex-pasture undertaken by Plantation Pine Products, Burraga Road, Gilmandyke.

Nutrient management

A second consideration is site nutrition, and the design and application of fertiliser regimes. Historically, there has been a site-based approach to management of plantation nutrition. However, FCNSW indicated that there has been difficulty in validating results of this approach through trials. As noted above, weed competition can negate fertiliser benefits, particularly on low fertility sites.

Post-harvest residue burning

The third issue is the routine practice of burning to remove or reduce post-harvest woody residues. While this approach is effective in removing woody debris, particularly on poorer quality sites with poor tree form where recovery has been lower, it may contribute to nutrient loss and reduce organic matter availability, and water retention, for subsequent rotations.

[7] A University of South Australia team is undertaking a FWPA and industry funded project titled: Development of a portfolio of alternative weed control strategies for use in plantations.

Tree planting stocks

All tree planting stocks used in the Central West are acquired from nurseries outside the region, including Blowering, Grafton, Tumut, Holbrook and Narromine in NSW and Colac and Gelliondale in Victoria. While there was no specific criticism of the quality of planting stocks available for establishment, growers (C. Berry, 2021 *pers. comm.*) noted that all tree stocks are sourced from areas which are at lower elevations and with quite different climatic conditions than are experienced in the region, particularly in relation to temperature. Notably, several private plantations experienced total failure historically due to frost and were re-planted with specifically hardened stock sourced from outside the region (J. Byrne, 2021, *pers. comm.*)

Silvicultural regimes

There are a number of aspects related to silvicultural regimes employed in the region which appear to be influencing the ability to maximise plantation productivity.

Plantation initial stocking rate

The historic regional standard for plantation establishment appears to have been 1,100 stems per hectare, regardless of site characteristics or management intent. Stakeholders questioned the validity of a blanket initial stocking rate across the region and indicated that this may be limiting productivity. Hume indicated that it focuses very carefully on stocking management to ensure planting density is adjusted to best suit specific site characteristics and management intent. Currently FCNSW establishes at 1,100 stems per hectare with a sawlog focused regime. PPP is establishing plantations for shorter rotation pulpwood generally between 1,300 and 1,400 stems per hectare (with an absolute minimum of 1,200 stems per hectare), with variation according to management regime and its own modelling.

Planting Row Direction

For soil stability and moisture retention, best practice site preparation is to contour rip, orientating cultivation across the slope with plantation rows following contours. Planting typically does not line up trees perpendicular to the contour rows. This can create a significant issue when first thinning extracts an outrow for mechanical harvester access and product extraction (applicable to traditional ground based, winch assist and cable harvest systems) (see Figure 4). Any side slope across the outrow is a risk to machine stability and often results in mechanical damage to edge trees. Therefore, except where side slope is minor (<2 degrees), outrows are almost always established perpendicular to the contour and the planted row. These outrows are wider, often two rows wide, and thinning between outrows is lighter in order to maintain a target residual stocking. The net result is suboptimal spacing and distribution of residual trees. One solution applied elsewhere is to maintain contour ripping, with planting rows established perpendicular to contours; that is plant-up and down the slope.

Regardless of this observation, it is certainly the case that careful attention to accuracy and effectiveness, including through operational quality control, in the

application of silvicultural plans is an essential tool to ensure the achievement of planned outcomes.

Regeneration versus re-planting

The practice of managing second and subsequent rotations as wilding regeneration appears to be relatively widespread within the smaller private estates in the region. This is not usual practice in other regions. Stakeholders suggested that regenerated plantations are typically harvested between 17 and 25 years of age, producing between 180 m^3 to 220 m^3 per hectare with log quality heavily weighted towards pulpwood (MAI of 8.8 to 10.6 m^3/ha/y). Based on project CWFH001, there are about 500 ha where this practice has been applied in the region, although this area may grow.

Figure 4: Delayed first thinning: Vulcan State Forest

Thinning regimes

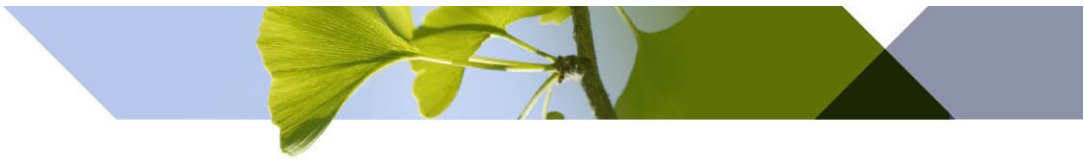
Another issue relates to the design and application of thinning regimes on the public and private estates. Plantations appear to typically have one thinning event, (nominally at about age 17), or are managed as unthinned stands. Rose (1999) noted that most mature stands on the private estate were unthinned at that time, which was most likely due to limited available markets (particularly pulpwood markets) for privately owned wood. A considerable proportion of such plantations subsequently changed ownership and are now managed by either FCNSW, Hume or PPP; some 9,000 ha remain owned by smaller growers. While most of those plantations have

now been harvested, there remains large areas of mature unthinned private plantations in the region. Current management of silvicultural intervention (thinning specifically), is highly variable in the private estate and appears dependent on the presence and quality of the management arrangements in place and the ability of the manager to secure markets for wood. On the public estate there is a considerable area of plantation which is planned for thinning. A proportion is now delayed beyond the nominal age of 17 and in some cases appears to be occurring as late as age 22. The driver for delayed thinning appears to be commercial, with unthinned stands containing a higher proportion of logs suitable for the AAM mill (Raglan). Where thinning has been delayed, there may be an absence of an adequate growth response. In a number of cases there has also been extensive stand damage from windthrow following delayed thinning (see Figure 5). Stakeholders consistently identified a need for a more sophisticated and nuanced approach to the design and application of silvicultural regimes.

Figure 5: Windthrow in stand scheduled for delayed first thinning

Short versus long rotation

An increasing proportion of plantations are being converted from long-rotation sawlog regimes to short-rotation pulplog regimes. For example, PPP is establishing plantations to be managed on 14 to 15 year rotations to produce pulpwood for the Borg facilities. This applies to existing plantations acquired as well as greenfield plantations established. Currently there are about 2,800 ha of plantation which are or will be managed for pulpwood only production. The increase in area of short



rotation plantations is not a concern in relation to biological productivity *per se*. However, when considered in the context of overall demand and processing capacity in the region, it represents a reduction in availability of plantations capable of producing the broad range of log products required.

Economics and management

The nature and operation of the region's forest product markets is widely recognised as having influenced plantation productivity. This is particularly the case for the private plantation estate, where historically private plantation owners have struggled to access local markets. There are four areas of focus to consider.

Exports

A lack of local markets was a key factor facilitating large volumes of privately owned logs to be exported from the region, either to China or to Visy (Tumut). Consequently, the mature plantations have been more or less liquidated and that area will not contribute meaningfully to regional wood supply, particularly sawlog supply for the short to medium term.

Maximising sawlog production

A lack of local markets was a key factor preventing broadscale application of silvicultural intervention (commercial thinning) in the private estate over a long period of time. It is therefore likely that total commercial volume and high quality (sawlog) log production have been compromised historically.

Maintaining plantation quality

Lack of confidence in markets was noted by stakeholders as one of the more important factors influencing decisions of some private plantation growers to allow harvested sites to regenerate rather than actively re-establishing those areas. While it currently represents less than 1% of the plantation area, there is a further 3% of small privately owned plantations which are over thirty years old or are currently being harvested. If the same approach is applied, this could result in a more significant long-term reduction in potential productivity.

Maintaining plantation area

There are currently about 11,836 ha of plantation estate (Greenwood Strategy, 2021) (13 % of the mapped area) in the region which are unplanted (refer Table 5). While there are a range of reasons, at least a proportion of this area will be suited to re-establishment or full land utilisation. About 3,944 ha of unplanted plantation land are situated among the smaller private ownership group. This represents some 33% of smaller private plantations and about 4.5% of the total plantation area in the Hub region which may potentially be lost from plantation production (refer Table 6). More broadly, there is a need to understand what proportion of the unplanted area across all ownership types is, in fact, viable for plantation establishment and if so, why it is not currently planted.

Table 5: Plantation area by age class/category in the Hub region.

Age class/category	Mapped area (ha)	Mapped area (%)
1-10 years	29,287	32.63%
11-20 years	23,306	25.96%
21-30 years	15,755	17.55%
30+ years	7,684	8.56%
Clearfell in progress	1,102	1.23%
Planting in progress	346	0.39%
Wilding regeneration	441	0.49%
Unplanted	11,836	13.19%
Total	89,757	100.00%

Table 6: Per cent age class/category by owner and owner type in the Hub region

Age class/category	FCNSW	Hume	PPP	Other private	Total
1-10 years	33.26%	54.68%	30.40%	12.23%	32.63%
11-20 years	29.18%	17.06%	20.07%	9.69%	25.97%
21-30 years	20.63%	1.81%	3.61%	9.82%	17.55%
30+ years	7.59%	5.33%	8.74%	18.34%	8.56%
Clearfell in progress	0.00%	0.00%	0.00%	11.91%	1.23%
Planting in progress	0.00%	0.00%	12.28%	0.00%	0.38%
Regrowth	0.00%	0.00%	0.24%	4.69%	0.49%
Unplanted	9.34%	21.12%	24.66%	33.32%	13.19%
Total	100.00%	100.00%	100.00%	100.00%	100.00%

Technology

In relation to productivity, the main technology opportunities are application of spatial information systems to assist in ensuring maximum utility of the region's plantation land base. The three larger plantation owners all utilise Geographic Information Systems (GIS) to support estate management. UAV (drone) technology is evolving rapidly and now often supports ground based validation processes. GIS coverage across the smaller private plantation estates is variable and dependent on the presence and quality of management for those areas.

Recovery and utilisation – current state

Stakeholder consultation suggests that utilisation and volume recovery is generally considered to be at a high standard in the region. In particular, a range of markets exist for a broad range of products, as well as systems and processes in place to support optimal distribution of products. Questions were raised by stakeholders about value recovery. Specifically, there were concerns noted about whether logs are going to the right place for maximum value. That concern is partly due to competition and tension between a number of contracted customers with requirements for similar logs for which there is limited availability from a constrained resource base. There are also key historic differences in approaches to recovery and utilisation between the public and private plantation estates, including the application of more restrictive log specifications for privately grown logs. It is important to note that there appears to be widespread recognition among processors of the impacts that the historic approach to private property wood has had and of a need to take a more holistic view of the region's fibre resources in the future in order to maximise value recovery.

Site

Accessibility

There are two specific accessibility issues which appear to have an influence on delivering optimal recovery and utilisation in the region.

Steep country

Both of the major harvest and haul contractors have specialised steep country harvesting crews operating. There are challenges with maximising recovery in steep country harvesting operations, predominantly driven by physical and cost challenges associated with extracting the full range of products from within a harvested area. In some cases this challenge is exacerbated by log damage as a consequence of rough and rocky terrain. A range of different harvesting systems (e.g. shovel logging, winch assist extraction and full cable systems), have been utilised in the region to address steep country challenges. While recognising recent harvesting technology innovations, it is not clear whether there is an approach which can routinely deliver the best outcome locally with respect to maximising recovery and utilisation of the full range of products from steeper areas.

Road classification

A number of supply chain actors noted that in some instances, classification of shire roads limits the potential range of haulage systems that can be utilised in the region. This influences the ability to economically and efficiently haul poorer form, variable length, marginal quality, lower grade and lower value logs.

Site quality

Site quality will influence plantation quality, particularly in relation tree form which subsequently impacts recovery and utilisation. As has been documented (e.g. Birk, 1992; Turvey, *et al*, 1993), plantation trees grown on ex-pasture sites are often characterised by excessive taper, multiple leaders and heavy branching. This has

severely limited recovery and utilisation of wood produced on many first rotation ex-pasture sites, leading to considerable waste. Another issue commonly experienced in plantations in the Central West is butt sweep. A number of growers and contractors commented on its extensive nature and its impact on recovery and utilisation.

There are influences of site quality on wood quality via impact on tree growth and ratios of wood types. Genetic impact on wood quality is more related to core wood attributes, which can be separated from growth related factors (Jenkin, *et al*, Draft). However, it is generally recognised that improved wood stiffness is correlated with slower grown trees on poorer quality sites due to a change in the ratio of wood types within a tree, not change in wood type *per se*.

Biology

The quality of genetics and tree planting stock planted in the region has improved considerably, with large parts of the estate now established with GF19 seed. This should result in improvements in tree form, and therefore recovery and utilisation, as second and subsequent rotation stands are harvested. Therefore, it is likely that a number of current issues influenced by biological factors affecting ability to produce wood from the mature estate suitable for regional log markets will resolve as these younger, better quality tree stocks mature and are harvested. However, there remains a question whether there are options to refine suitability of genetics and tree planting stocks to this region specifically.

Silviculture

As identified previously, plantations in the Central West have been typically planted at 1,100 stems/ha and are subject to either a no thin or single thin (usually age 17) silvicultural regime with a target clearfell age of 30 years. Observation suggests that stands not originally slated for thinning, as well as some stands where on-time thinning was planned but not achieved, are now subject to delayed first thinning, with the purpose (at least partially) of meeting commitments for specific log grades and sizes. On the larger private estates (e.g. Hume and PPP), there is evidence that growers are actively applying, or considering application of variable silviculture approaches with issues such as stocking rate, thinning regimes and clearfell age adjusted to address site conditions and economic objectives. For the smaller private plantation owners, there is considerable variability in silvicultural management, which is highly dependent on the presence and quality of forest management services, along with landowner intent and, perhaps most importantly, access to markets. The small but increasing area of second rotation plantations through wilding regeneration is an example of this, with other plantation areas subject to a spectrum from little or no management between establishment and clearfell, through to intensive and timely application of silvicultural interventions. The relationship between silviculture and recovery and utilisation is influenced by a number of other factors considered in this report. However, it seems that the significant variability in silvicultural management influences tree size, and therefore piece size, which, when compounded by other factors, serves to limit recovery and utilisation options. The influence of silviculture on recovery and utilisation due to tree

and log form issues is less clear but is likely to be an issue in smaller plantations, particularly those that are naturally regenerated, or where poor genetics and/or lack of silvicultural intervention applies to mature stands.

Economics and management

Management of harvest and haulage capacity

There has been a considerable reduction in harvest and haulage capacity in the region as the volume of private property harvesting has declined over the past few years. There is a general view that harvest and haul capacity within the region is satisfactory as long as harvesting activity is well planned. One contractor noted that there was a historic expectation that they would be capable of providing flexible and responsive "surge" capacity. However, with reduction in capacity, that flexibility can no longer be relied upon as machinery has been sold and crew numbers reduced permanently.

Supply chain communication

A number of examples indicate that there are material opportunities to improve supply chain communication to support improved recovery and utilisation. A tacit example relates to the shared understanding about blue stain in logs. It appears that growers have indicated to contractors that logs exhibiting blue stain are not suitable for sawlog markets. However, processors have indicated that in a resource constrained market, they are comfortable with purchasing logs with blue stain as it does not impact grade for structural sawn timber. The result has been inadequate utilisation and distribution of logs to the most appropriate and highest value end use. An example was where 15,000 m^3 of logs exhibiting blue stain were exported to China because it was assumed that they would not be accepted by the local sawmill. Other, less explicit examples of poor communication flows indicated influencing the application of log specifications in particular. It is suggested that at times information passes through too many people, or the information is incomplete, and compounded by an absence of shared understanding of application of log prescriptions to ensure that recovery and utilisation are maximised.

Log specifications and log making

One issue identified for the region was the relative complexity of log specifications. Stakeholders identified that there are up to 27 log products specified in the region. Realistically there are only three log types demanded: preservation log, sawlog and pulplog. Stakeholders expressed the view that recovery and utilisation are high in the region because of a broad spread of log types demanded by the market. However, there are instances of apparent underutilisation and lower recovery, specifically related to poor tree form. Lengths of butt sweep are routinely docked from logs due to actual or perceived problems for processors to handle them. Given the weighted volume distribution at the butt-end of a log, this potentially represents a significant unrecovered or underutilised volume. General stem sweep is common in the region and is typically docked out of logs, limiting potential volume of wood recovered from some individual trees.

Alternatives for pulpwood

There is general recognition of the challenge of unrecovered fibre, particularly on low quality sites. In one instance observed, stand quality and subsequent utilisation and recovery were so poor that the contractor was paid on an hourly rate rather than a production rate in order to liquidate the stand (see Figure 6). There have been attempts to address the issue with alternative approaches to loading and transporting of residual material with awkward dimensions not suited to standard haulage configurations. Currently there is not an operational solution.

Figure 6: Significant harvest residue from poor quality stand: Hopes Road, Essington State Forest

It was also noted that some heat energy requirements for the HPP mill are derived from burning sawmill residues. It is possible that at least a proportion of these residues could be diverted to the Borg facility as additional fibre, if the sawmill was to transition from wood-fired energy to gas, or potentially utilise surplus energy generated by the MDF facility. However, it is also important to note that this approach would not be consistent with current energy policy, as the move from green to brown energy would not be considered greenhouse gas friendly.

Technology

Optimising software

The application of harvesting head optimising software is strongly supported throughout the supply chain. There is also evidence of a need for improvement in its application. While the technology is considered to be very good, it is less operational in poorer quality stands where machine operators continue to make most of the log-making decisions. Also, poor mobile telephone reception in many parts of the region are a barrier to timely download of and upload of specifications and data. Subsequent rotations with improved genetics will see an improvement in the general quality of stands and therefore optimising software will become more broadly applicable. Stakeholders noted that optimising software is particularly useful in thinning operations. It is possible that use of improved genetics are improving tree form. The reporting tool/interface (STICKS) is considered to have significant potential which is currently not being fully realised. Some administration issues have been identified, particularly in relation to the interface between creation and provision of optimising files by growers to harvesting contractors.

Wood quality

There is currently no systematic approach to testing for wood quality and suitability in standing trees before log making, or for logs at roadside storage prior to distribution. However, there is considerable interest among supply chain actors to consider the application of technology such as the Resi-Tool to determine standing tree wood quality and assist with ensuring optimal utilisation and distribution.

POTENTIAL OPPORTUNITIES

The project has identified a range of potential opportunities to generate improvements in plantation productivity, recovery and utilisation of harvested logs in the region. In this section, identified opportunities are described and proposed approaches for delivering improvements are explored, including quantification of potential improvements (where possible), and setting priorities for action by the Hub.

Describing the opportunities

Opportunities for improvement are presented in the context of the five factors applied to description and analysis of the current state. Some opportunities are likely to deliver improvements across all three areas of plantation productivity and recovery and utilisation of log products. Therefore, opportunities are presented as a whole. It is important to recognise that there will necessarily be some interplay and overlap between opportunities across the five factors that have been assessed against. For example, consideration of genetics and silviculture may augment each other with the application of more nuanced and tailored solutions to site specific conditions.

Site

Road classification and haulage systems

Road classification limitations constrain haulage systems which can be widely used in the region. This can have a knock-on effect with respect to recovery and utilisation, because the economics of transporting lower quality and lower value logs can be compromised. Use of rural roads for transport of logs routinely has significant social license considerations and can present serious challenges for local government authorities. In the Central West, a key point of contention is availability of B-double and Mini-B-double classifications for regional roads. There are concerns in regard to introducing new haulage systems in regional areas, particularly with larger trucks. However, there are good examples where reductions in number of truck movements and improved haulage technology and efficiencies have reduced road maintenance requirements and delivered a safer haulage outcome. There is a need for a stand-alone study to objectively assess the potential for alternative approaches to road classifications in the region.

Biology

Deployment of improved genetics is an opportunity for improved plantation productivity, recovery and utilisation at harvest. Improved genetics can influence wood properties. Some of these potential gains are already realised by current use of improved genetic material in the region, simply due to affordability and availability. Specific opportunities remain which could further enhance the gains beyond those already likely to be realised.

Regional genetic suitability

Johnson *et al* (2008) identified the potential importance of genotype by environment (GxE) interactions in relation to *P. radiata* performance of New Zealand seed lots in

Australia generally and in New South Wales specifically. They recommended that a better understanding of GxE relationships and combining improved New Zealand genotypes with regionally specific and tested local genotypes to deliver site and regionally specific GxE deployment. Currently none of the seed utilised in the region is derived from regionally specific seed orchards or genetic material and no recent research has addressed genetic suitability to environmental attributes in the Hub region. Therefore, there is potential to augment productivity gains from improved genetic material being deployed in new establishment and re-establishment, with seed specifically selected to suit local conditions. However, without the requisite research, it is not possible to assess whether that potential can be realised and whether any quantified benefits justify the potential investment. Further research is required to determine the benefits which could be achieved, in terms of growth and form, and potential return on investment from a program of identifying, breeding and deploying regionally specific genetics from a seed orchard combining quality New Zealand genotypes with select genotypes from within the region.

Matching genetics with management intent

Regardless of source, there is a wide range of seed available with a variety of desirable attributes at $1,500 and $25,000 /kg. *P. radiata* seed varies in size; New Zealand uses three seed grades (1) 20,000-25,000 seed/kg, 2) 25,001-33,000 seed/kg, and 3) 33,001-50,000 seed/kg) (Menzies *et a*l1991, p.26). Therefore, seed costs vary from $0.03 to $1.25/seed. The range of regional site quality and increasing variation in management intent means that not every situation will warrant deployment of the best and most expensive genetics. For example, managers of short rotation pulpwood crops will focus on volume performance, whereas managers of long rotation, high quality sawlog crops will be mindful of form and wood quality issues. The most suitable genetic material for these two options is likely to be considerably different and to have a considerably different cost profile. A better understanding of available genetics, aligned with management intent and site characteristics (GxExM) could deliver considerable value for growers and improve capacity of the plantation estate to more specifically address market requirements.

Silviculture

There is considerable scope to review silvicultural practices in the Central West to realise productivity gains through developing a more targeted and nuanced approach to plantation management.

Post-harvest burning

In the context of local harvesting operations, post-harvest burning offers a cost-effective and physically efficient mechanism for dealing with residues and readying sites for a subsequent rotation. This is particularly the case for sites where poor quality tree form has resulted in low log recovery. Nevertheless, there is a strong argument for ceasing this burning of post-harvest residues. There is considerable evidence that burning of post-harvest residues, foliage and bark results in a significant reduction in available site nutrition and water retention capacity. Keeves (1965) provided evidence of a second rotation decline for *P. radiata* growing in South Australia. Management practices changed and operational results indicated a 60 to

70% increase in productivity (O'Hehir & Nambiar, 2010). Such practices have been adopted across many Australian industrial plantation estates. Post-harvest burning is being phased-out of some hardwood plantation operations in southern Australia driven by requirements of voluntary third party certification schemes. Regardless of analysis of ceasing or continuing this practice, it may be that certification requirements and land management emissions policies limit its future application.

Weed management

While there are recognised weed management challenges in the region, there is a lack of understanding of the impact of weeds on plantation productivity or how to address the challenge locally. Any targeted research should be informed by current research programmes. An option is to link with FWPA's project undertaken by the University of South Australia considering alternative weed control strategies (FCNSW is a project collaborator). Other avenues include through the Forest Industry Herbicide and Pest Management Consortium, coordinated by the University of the Sunshine Coast. While it is an important area to address, any gains are likely to have a very long lead time.

Nutrient management

There is an opportunity to review historic nutrient management activity in the region to determine whether the current approach is most appropriate or whether there is scope to improve productivity. As with weed management, this could be addressed through linking with current FWPA projects and it would make sense to align with existing research efforts.

Tree planting stocks

There is an opportunity to examine potential productivity gains by utilising tree planting stocks grown in the region. It is suggested that tree planting stocks grown in nurseries located in warmer, lower altitude sites, may not suit the Central West. However, establishment of a nursery is a significant investment and would require a strong business case. A standalone study to examine benefits and the commercial case for establishing a local nursery should be undertaken. Ideally a study would consider projected re-establishment schedules across the existing estate, as well as likely and potential plantation expansion in the region.

Silvicultural regimes

A consistent theme is the need for a more nuanced approach to development and implementation of silvicultural regimes across the region's plantations, matched to site conditions and management intent. As part of an FWPA project, Jenkin *et al* (draft) presents a comprehensive review of site, silviculture and genetics impact on wood quality, providing a range of insights and understanding of opportunities. There is also an important interface with genetic deployment, as described below. The primary issue is geographic (site) variability within the plantation land base, combined with increasing variability of management intent (e.g. short versus long rotations). The inference is that establishing plantations at 1,100 stems/ha and applying a single thin silvicultural regime over a 30 year rotation is not sufficiently sophisticated to deliver optimal productivity while supplying log types required to

meet processor requirements. In addition, there is real potential to manage silviculture for specific wood quality requirements.

A project should address current and potential silvicultural practice and develop a rigorous and defensible toolbox of silvicultural regimes to be applied to specific circumstances within the Hub with the aim to maximise fibre productivity and product mix suited to the market. Hypothetically, this project could look, for example, at which geographic and commercial circumstances warrant examination of short rotation pulp-only regimes, or the intersection between treestock and genetic quality with site quality for longer rotation, two-thin silvicultural regimes for maximising wood quality and volume to structural end-uses.

Economics and management

Actions in this category present the greatest opportunity for early gains with respect to potential improvements in recovery and utilisation.

Maximising land utilisation

There are approximately 90,000 ha of plantation land within the Hub boundary of which about 11,971 ha are currently unplanted (13.3 % of the mapped estate). Project CWF001 identified that a considerable proportion of unplanted area occurs on smaller private holdings, estimated at approximately 3,220 ha (34 % of that ownership category). When the area of wilding regeneration is included (441 ha), the potential proportion of the smaller private plantations which are underutilised is about 40%. A range of reasons are posited for areas to remain unplanted, including active decisions to not replant, accessibility issues, fallow and productivity or environmental exclusions. There is a need to understand what proportion of this area is able to be planted and why it is not currently planted. An improved knowledge base will facilitate actions focused on more fully exploiting the available land base to potentially increase productivity. For example, bringing 50% of this land base into production at an average MAI of 14 to 16 m^3/ha/y over 30 years, would result in a long-term increase in available fibre of 85,000 to 97,000 m^3/y. A first step to improved knowledge about the unplanted area is to undertake a more detailed assessment of smaller privately owned plantations to quantify the net planted area and to describe the unplanted area more accurately.

Maximising plantation quality and production of a full range of products

Historically plantations in the region have been established with the broad intent of sawlog production over a long rotation. However, as first rotation plantations have been clear felled, silvicultural regimes are becoming more diverse. For example, PPP has made an active decision to grow short rotation plantations for pulpwood production and an increasing area of privately owned plantations is being regenerating with wildings. Future land-use decisions on private property are clearly the prerogative of individual landowners and in many cases will be made on a rational and well-informed commercial basis, such as the PPP approach. However, anecdotal evidence suggests that a decision to not replant is in many instances being driven by a lack of understanding about and confidence in regional wood products markets to justify the expense as well as a lack of certainty about other land-use options. It is positive that most of the estate is being maintained for

softwood fibre production rather than being converted to other land uses. However, the ability of some of the estate to continue to contribute to fibre supply at maximum levels of potential is compromised. One of the primary drivers for Regional Forestry Hubs is to increase opportunities to expand the plantation footprint into the broader agricultural landscape. In this instance, there is an opportunity to focus on maintaining the existing private plantation estate. One solution is to identify mechanisms available to the industry to encourage, support or provide incentives and commercial structures which encourage landowners to re-plant and focus on maximising fibre production. Other Regional Forestry Hubs (e.g. Tasmania, the Green Triangle and South-west Western Australia), are researching solutions for maintaining and expanding smaller private plantations through more effective commercial arrangements with the forest and wood products supply chains in those regions. There is considerable opportunity for the Hub to coordinate with other Regional Forestry Hubs around this topic as many of the issues are consistent between regions.

In field chipping

Observational and anecdotal evidence suggests that large volumes of unrecovered pulp grade fibre, specifically in poorer quality stands, occurs throughout the region. The main constraint to utilising this fibre is that it is either physically impractical (form) or economically unfeasible (cost) to transport it in log form to a processing facility. In fact, a number of approaches to access this material have already been trialled with limited success.

One option which is yet to be tested is in-field chipping. In-field chipping harvesting systems are widely used in the hardwood plantation sector in Victoria and Western Australia and the equipment and technology has previously been adapted to some formats of softwood harvesting. Challenges to successfully deploying in-field chipping systems include how to deal with larger log diameters, poor form and short lengths and potentially a need to coordinate different harvesting and transport systems on one site. However, there is potential to significantly increase recovery from poorer quality stands with this approach. An immediate opportunity is to determine the volumes which could be accessed and whether an economic case exists to introduce this approach on an ongoing basis. An added advantage is that increased utilisation is likely to result in reduced establishment costs for subsequent rotations. Therefore, even if the material is removed at no stumpage value, there is still potential for an economic gain.

Centralised log yarding

Centralised log yarding is a widely used practice in North America, and to some extent in other countries, and has potential application in the Hub. In particular, a concentration of processing capacity at Oberon, relatively short-haul distances to the other two regional processors at Raglan and Burraga, and recognised challenges with utilisation of small diameter logs all support consideration of this approach. There is a body of literature dedicated to the economics and operational feasibility of centralised log yards, with specific focus on management of small and underutilised log products (Dramm *et al*, 2004). A well-designed centralised log yard, operated with sophisticated logistics, has the potential to improve distribution of log

products to the best and most appropriate end market and may also generate opportunities to increase recovery and utilisation of lower grade and smaller logs (Huka & Gronalt, 2018). There are also potential challenges to the efficacy of this approach, including limitations on harvest and haul of longer logs, costs of double handling and potential for lost value in forest. Consequently, there is a clear opportunity to undertake a feasibility study to quantify productivity, recovery and utilisation implications of this approach and fully assess the economic case.

Log specifications

Rationalise log categories

The link between complex log specifications and improved productivity, utilisation and recovery is not necessarily overt. As noted, stakeholders have identified that there are up to 27 log types specified for a region with four processors and three basic products (e.g. sawlogs, preservation logs and pulpwood). This appears to be unnecessarily complicated. Rationalising to a smaller number of log types and ensuring that specifications are applied consistently across all forest ownership categories is likely to reduce confusion for harvesting operators and growers to result in efficiency gains and improved likelihood of log making and distribution focused on the best value outcome. This is a relatively easy outcome to achieve through establishment of a working group, at no cost, to develop a new coordinated approach.

Field test potential log specification changes

Two specific opportunities have been identified with potential to expand available fibre in the short term.

The first is to reduce SED requirements for first thinning and unthinned clearfall pulpwood from 8cm to 6cm and first thinning sawlogs from 18cm to 16cm. Younger, more flexible stems are less prone to shattering at harvest and this shift has the potential to increase volume recovery. However, there are potential challenges associated with loading and haulage of smaller diameter logs. Therefore, this should be tested in field to determine its feasibility. Second, with improved sawmilling technology, current specifications around shorter lengths and sweep (particularly butt sweep) could be significantly relaxed, to improve sawlog recovery from the largest part of the log. Again, this opportunity should be field tested to determine its feasibility.

The project has identified potential gains of between 18,000 and 54,000 m^3/y from log specification changes but these estimates are subject to in-field testing to determine actual gains that could be realised.

Technology

There is increasing recognition of introduction and adoption of new and emerging technology to improve utilisation of available wood resources (Greenwood Strategy, 2021). While the forestry sector has generally benefited from increased mechanisation, automation and use of data, it is generally considered to lag behind other sectors (Allott *et al*, 2020). Key to capitalising on the new wave of industrialisation (referred to 'Industry 4.0'), is collection, management, integration and

application of data to drive efficiencies and greater productivity. Value chain actors in the Hub have started to explore this opportunity, with use of harvesting head optimising software and the data collected.

Choudry & O'Kelly (2018) present a useful summary of the 'building blocks' for moving from traditional to precision forestry systems as well as promising emerging technological advances (refer Table 7). It is apparent that forest managers in the region have progressed well along this path. However, there is also considerable opportunity to explore some of these advances further to improve outcomes.

Table 7: Emerging technological advances in precision forestry (Source: Choudry & O'Kelly, 2018)

Treestocks	Silviculture	Harvesting	Delivery	Value chain
Advanced genetic improvements	Site-specific management	Digital inventory	Remote/ automatic loading	Forestry planning models
Automated nurseries	Fire monitoring	Mechanised harvesting	Wood logistics optimisation	E-dashboards
	Pest and disease monitoring			Field support tools
	Water-management systems			Advanced analytics
	Mechanised operations			

Harvest head optimising software

Stakeholders indicated a significant amount of data being captured by harvester head technology, but it is not fully utilised in terms of driving improved knowledge and on-ground outcomes. Given broad support for the technology and its application along the whole value chain, there is a significant opportunity to fully explore the value that can be gained for all supply chain actors through improved specification of data requirements and integration of use of technology. A first step in this opportunity can be readily realised, at little or no cost, through establishment of a working group comprising representatives throughout the supply chain, including forest growers, contractors and wood processors.

Future data integration potential

Demonstrated success with data collection, management and communication opportunities with harvesting head data could feasibly establish a basis for increasingly sophisticated *big data* management in the region. Because most of the wood grown in the region is processed locally, and because the supply chain is reasonably well integrated, there is potential to develop data and technology

solutions which deliver benefits applicable to the entire supply chain. The ability to inform optimal plantation stewardship (design, establishment, management and product supply), to consider whole of value chain integration and deliver optimised wood flow modelling, utilising multiple data sources could be an achievable aim for the region's forest and wood products sector. There are material hurdles to be overcome to achieve this outcome. In particular, it challenges commercial preconceptions about how legally separate entities work together for a common objective. There are also practical constraints related to the quality of the regional telecommunications infrastructure which mean that mobile and internet data transfer capability are a potential barrier.

Wood quality

Jenkin *et al* (Draft) documents variation within trees, across sites and within regions. This is consistent with observations within the Hub. Knowledge about standing wood quality can significantly improve how logs are recovered and distributed to the highest value end market. Technology such as the Resi-Tool, can provide managers and operators with close to real time information to inform operational decision-making. There is an opportunity to link to other FWPA studies addressing wood quality assessment.

Delivering improvements

A critical focus area for the project is to attempt to quantify potential gains and provide an indication of priorities and recommendations to progress opportunities and deliver improvements.

Quantification of potential gains

Increased fibre availability

The opportunities identified in this report have the potential to generate up to 564,000 m^3/y of additional fibre in the long-term. This would represent an increase in the region's average MAI to between 20 and 22 m^3/ha/y (at age 30 years), or an average MAI increase of up to 6 m^3/ha/y. While this is a significant potential increase (and noting these improvements are not necessarily exhaustive), it is consistent with other high performing major softwood plantation regions, such as the Green Triangle and Gippsland. Importantly, this is an upper limit for potential gains and assumes that each potential opportunity is acted on and delivers fully. Realistic potential gains are likely to be in the order of a long-term MAI increase of between 2 and 4 m^3/ha/y (at age 30 years). This represents a potential long-term increase in available fibre of between 180,000 and 360,000 m^3/y. Even at the lower end, this is a productivity increase of 12% to 14%, assuming that current long-term sustainable harvest levels are between 1.3 and 1.5 million m^3/y (an average MAI of 14 and 16 m^3/ha/y respectively) (refer to Table 8)

Table 8: Potential volume gains

Current sustained yield		MAI increase 2m³/y		MAI increase 4 m³/y	
Volume (m³/y)	MAI (m³/ha/y)	Volume (m³)	%	Volume (m³)	%
1,300,000	14	1,480,000	14	1,660,000	27
1,500,000	17	1,680,000	12	1,860,000	24

Availability of required log grades

It is more challenging to quantify the potential gains in relation to availability of the range of log grades required by processors in the region.

Reliability

The application of quantified estimates of potential productivity gains is based on the experience of the authors. Where possible actual data or literature evidence has been used. Where there is no realistic ability to provide an estimate of potential gains, this has been noted.

Action categories

Potential actions identified through the project can be categorised as follows:

1. Supply chain communication

   These are projects which can be delivered at little or no cost through the establishment of working groups or sub-committees of the Hub, with possibly some IT linkage upgrades, to further explore the opportunity and identify specific outcomes.

2. Whole of industry collaboration

   These are projects where there are identifiable gains for the forest and wood products sector in the Hub that are most effectively and efficiently delivered by collaborative effort with other Hubs, research and/or industry organisations, or there is work already underway in other regions which the Hub can contribute to for maximum return on investment.

3. Short term specific regional projects

   More involved projects of direct benefit to the Hub for which the outcomes can be delivered over a relatively short timeframe.

4. Medium term specific regional projects

   More involved projects of direct relevance to the Hub for which outcomes are likely to be delivered over a longer timeframe.

Setting priorities

A simple approach has been applied to identifying and setting priorities for future action by the Hub to address opportunities, which is presented in the matrix in Table 9.

Table 9: Matrix approach for identifying and setting Hub priorities

	Low effort	High effort
High impact	Priority 1 Low hanging fruit – short term gains for little effort which can deliver early benefit	Priority 2 Medium to long term and potentially complex projects with significant potential gains
Low impact	Priority 2 Short to medium term projects that deliver minimal returns with minimal input required	Priority 3 Complex or contentious projects with either no prospect of early returns or dubious long term returns

RECOMMENDED ACTIONS

Twelve recommended actions have been identified for consideration by the Hub. This section provides a summary of the recommendation actions that are presented in Table 10 and described in more detail on the following pages. Appendix 1 provides additional detail supporting each of the recommendations, including quantified estimates of potential productivity gains where it is feasible to do so.

Supply chain communication actions

Four Priority 1 actions have been developed which comprise low cost, low risk projects that have the potential to productivity improvements up to 54,000 m^3/y. The four proposed actions are focused on improving the approach to log specification and the transfer of log related data through the supply chain to improve log distribution and log making outcomes. The actions are:

1. Undertake a field trial for SED reduction from 18cm to 16cm for logs to HPP and AAM from first thinning operations and from 8cm to 6cm for pulplogs.
2. Undertake a field trial of relaxed sweep and length combination specifications for logs to HPP, AAM and AUT.
3. Overarching review of log specifications to determine if reduced complexity and improved log making and distribution can be achieved.
4. Overarching review of the management and communication of harvest head optimising software and data.

Whole of industry collaboration actions

Two Priority 2 actions have been identified that would involve the Hub collaborating with other Hubs and research providers to contribute to and benefit from whole-of-industry workstreams. These proposed actions reflect opportunities where there is work already occurring elsewhere and the Hub will gain more benefit and better cost-effectiveness from the collaboration. The proposed actions have the potential to deliver up to 45,000m^3/y in productivity gains. The actions are:

1. Reviewing and developing commercial measures and structures available to encourage reestablishment and proper management of private woodlots.
2. Investigation of in-field wood quality testing (eg the Resi-Tool) to determine its practical and commercial application and benefit for in-field decision-making on log making and distribution[8].

Short term regional actions

Two Priority 1 actions have been identified for regionally specific projects to be undertaken over the short term which can deliver improved information to inform future action by the industry in the region. These actions have the potential to deliver

[8] The project team is aware that HPP has employed the Resi-Tool across the region and continues to do so.

up to 14,000 m^3/y in improved productivity as well as unquantified supply chain efficiencies, depending on the outcomes of the work. The actions are:

1. Detailed mapping of the smaller privately owned plantation estate to consolidate and augment the improved information delivered in Projects CWFH001 and CWFH002. This project would have additional benefits with respect to infrastructure planning and fire management.
2. Preliminary feasibility study of a centralised log yarding operation to determine practicality for the supply chain in the region and to define and quantify benefits.

Medium term regional actions

One Priority 1 action and three Priority 2 actions have been developed which represent regionally specific projects which can be undertaken and deliver outcomes over the medium term. These projects have the potential to deliver up to 420,000 m^3/y in future productivity gains. They are primarily focused on potential interventions to improve biological productivity. The actions are:

1. Review and refinement of regionally suitable silvicultural regimes to deliver the best silvicultural outcome considered against site characteristics and management intent.
2. Review and cost-benefit analysis of developing a regionally specific tree breeding program and seed orchard.
3. Feasibility and cost-benefit analysis of a regional nursery.
4. Review of unplanted areas to determine what area can potentially be brought into production.

Table 10: Summary of proposed actions to increase plantation productivity, utilisation and recovery of harvested products

Action Category	Priority 1	Priority 2
Supply chain communication	• Undertake a field trial for SED reduction from 18cm to 16cm for logs to HPP and AAM from first thinning operations and 8cm to 6cm for pulpwood. • Undertake a field trial of relaxed sweep and length combination specifications for logs to HPP, AAM and AUT. • Overarching review of log specifications to determine if reduced complexity and improved log making and distribution can be achieved. • Overarching review of the management and communication of harvest head optimising software and data.	
Whole of industry collaboration		• Reviewing and developing commercial measures and structures available to encourage reestablishment and proper management of private woodlots. • Investigation of in-field wood quality testing (eg the Resi-Tool) to determine its practical and commercial application and benefit for in-field decision-making on log making and distribution.
Short term regional	• Detailed mapping of the smaller privately owned plantation estate to consolidate and augment the improved information delivered in Projects CWFH001 and CWFH002. This project would have additional benefits with respect to infrastructure planning and fire management. • Preliminary feasibility study of a centralised log yarding operation to determine practicality for the supply chain in the region and to define and quantify benefits.	
Medium term regional	• Review and refinement of regionally suitable silvicultural regimes to deliver the best silvicultural outcome considered against site characteristics and management intent.	• Review and cost-benefit analysis of developing a regionally specific tree breeding program and seed orchard. • Feasibility and cost-benefit analysis of a regional nursery. • Review of unplanted areas

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APPENDICES

Appendix 1: Detailed recommendations

The project has identified 12 recommended actions, which represent priority 1 and priority 2 opportunities for the Hub to consider.

This appendix provides a detailed summary of proposed actions, presented in line with the categories and priority setting approach outlined above.

Priority 1 actions

Proposed action	Rationale and proposed approach	Potential gains		
		Measure	Low	High
Review and refinement of regionally suitable silviculture regimes	A stand-alone study to better understand the potential productivity impact of nuanced silvicultural regimes, including factors such as plantation design and stocking and thinning practices, to deliver the best silvicultural outcomes considered against site characteristics and management intent.	MAI (m^3/ha/y)	0.5	1.0
		Volume (m^3/y)	45,000	90,000
Detailed mapping of smaller privately owned plantations	CWFH001 and CWFH002 have delivered a significant improvement in the knowledge base regarding the smaller private plantation estate. These projects have also identified that there is additional information which can be developed in order to enhance the potential for these plantations to continue to contribute to regional fibre supply in the long term.	MAI (m^3/ha/y)	0.15	0.5
		Volume (m^3/y)	14,000	45,000
Field trial of SED reduction for first thinning operations	Proposed field trial to test the practicality (eg harvest and haulage challenges) of reducing small end diameter for T1 operations to 18cm to 16cm for sawlogs and 8cm to 6cm for pulplogs, and more accurately quantify potential benefits in terms of additional fibre availability.	MAI (m^3/ha/y)	0.1	0.2
		Volume (m^3/y)	9,000	18,000
Field trial of relaxed sweep and length combination specifications	Project to explore the opportunity to relax sweep and length combination specifications to reduce waste of butts (0.5 to 2m length typically). Field trial to quantify additional fibre availability and assess practical challenges.	MAI (m^3/ha/y)	0.1	0.3
		Volume (m^3/y)	9,000	36,000
Preliminary feasibility study for development of a centralised log yard operation	To test the case for establishment of a centralised log yard at Oberon to improve recovery and to optimise distribution of fibre to the best and highest value use. There are a number of potential benefits and challenges with this opportunity which require a detailed, stand-alone project to assess.	Cannot be quantified at this stage		
Review of log specifications	Currently cutting for 27 log products in the region, with variability between growers. Review of log specifications could create efficiencies and better distribution. This initiative is about efficiencies rather than additional volume. Also improving “level playing field” between growers.	Cannot be quantified at this stage		
Review of management of harvest head	This software is widely in use and well supported. However, it appears that there are advantages to be gained through simplification, improved communication, process and	Cannot be quantified at this stage		

optimising software and data	training. This would be readily addressed through establishment of a discrete working group. Benefit would be in ensuring distribution of fibre to best and highest value market point.

Priority 2 actions

Proposed action	Rationale and proposed approach	Potential gains		
		Measure	Low	High
Review and cost-benefit analysis of developing a regionally specific tree breeding program and seed orchard	Historical genotype work has been focused on the south-west slopes. There is a low correlation between NZ and Australian performance. Focus continues to move towards deployment of combined Aus and NZ germplasm. Integrating genetic decision making with management intent and site characteristics to maximise the deployment of suitable provenances matched with industry requirements would provide additional value. This is a potentially significant project, probably delivered in a number of stages. It requires careful attention to scope. It presents the single biggest potential gain opportunity for the region.	MAI (m^3/ha/y)	0.5	2.0
		Volume (m^3/y)	45,000	180,000
Feasibility and cost-benefit analysis of a regional nursery	This potential project would examine whether there is a benefit to be had. The first stage is to better understand whether there is an actual issue with tree stocks sourced from other regions. The second stage is to demonstrate the business case for establishing a regionally located nursery.	MAI (m^3/ha/y)	0.25	1.0
		Volume (m^3/y)	22,500	90,000
Review of measures to encourage reestablishment and proper management of private woodlots	Potential market driven incentives to re-establish (rather than regenerate) and actively manage the small private estate. Potential to consider what other Hubs (eg Tasmania and Green Triangle) are doing in this space.	MAI (m^3/ha/y)	0.25	0.5
		Volume (m^3/y)	22,500	45,000
Review of unplanted areas (in addition to private woodlot mapping)	About 13,200 ha (14 %) of the mapped plantation base is currently unplanted. This is a second stage project (following the private property mapping exercise), intended to develop an understanding about why this is the case (eg access, failure, fallow) across the estate and to identify and quantify opportunities to establish or re-establish plantations in some of this area.	MAI (m^3/ha/y)	0.1	0.65
		Volume (m^3/y)	9,000	60,000
Resi-Tool study	The Resi-Tool has been used in the region and appears to have some value. There are reported challenges in other regions with statistical validity. Consider a project to review and	Cannot be quantified at this stage		

	field test the Resi-Tool and other value predictive methods this in the region. Project would identify whether or not there are gains and quantify them.

Appendix 2: Stakeholders consulted

Organisation	Representative	Position
Forestry Corporation of NSW	Jason Molkentin	Regional Manager
	Russell Riepsamen	Planning Manager
	Euan Scott	Harvesting Forester
Australian United Timbers	Phil Burke	Owner
Hume Forests	Jake Lazarus	General Manager
Highland Pine Products	Mike Bitzer	General Manager
	Peter Seve	Commercial Manager
Plantation Pine Products/Borg	Chris Berry	Wood Resources Manager
AAM	Craig Neale	Operations Manager
Oberon Shire Council	Kathy Sajowitz	Mayor
	Gary Wallace	General Manager
Mangan Logging	Chris Mangan	Director
	Michelle Mangan	Director
Pine Harvesters	Grant Phillips	Owner
	Harrison Phillips	Director
Rosin Forestry	Peter Rosin	Owner
Byrne Rural Contracting	John Byrne	Advisor
Consultant	Frank Hanrahan	Advisor
Rose Forestry	David Rose	Advisor
Penrose Pine Products	Peter Cush	Owner
PF Olsen Australia	Ray Krippner	Senior Forester
AgriWealth	Hugh Dunchue	Head Forester
Visy	Kenneth Epp	Principal Advisor - Forestry
	Dean Hawkins	General Manager – Fibre Resources
Blayney Shire Council	Rebecca Ryan	General Manager
Central West NSW Forestry Hub	Craig Taylor Heath Molden	Hub Manager