Forest & Wood Products Australia

Mayday Hill Consulting

Forest Operations and Supply Chain Research Investment Plan

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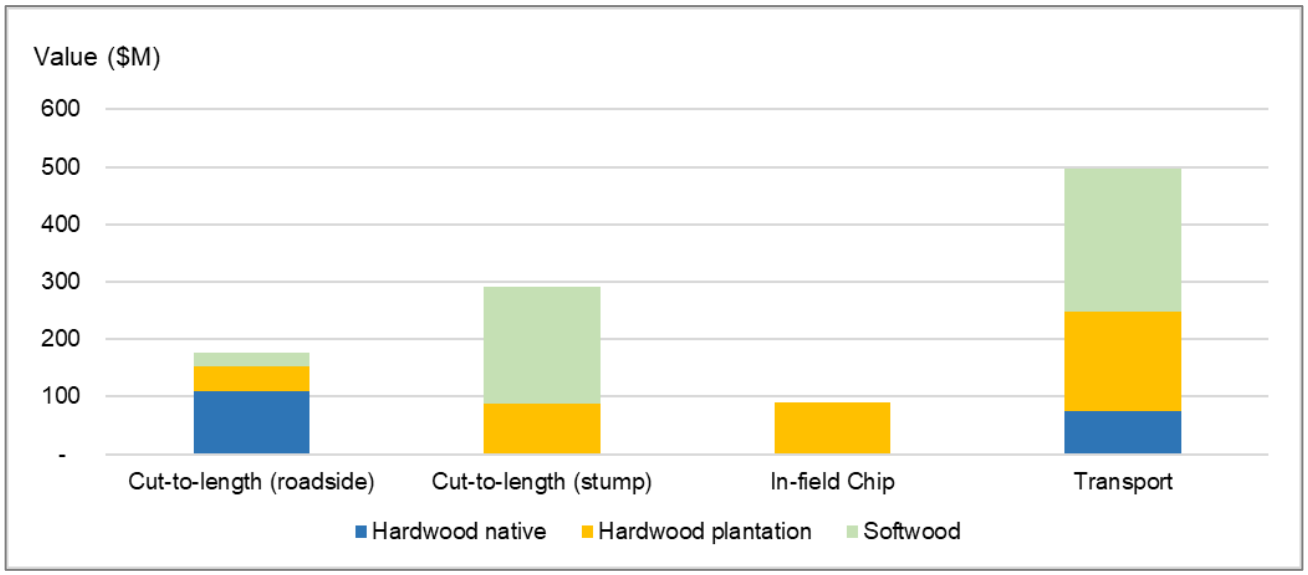
Executive Summary

This Investment Plan establishes a blueprint for RD&E investment for the Australian forestry sector in the supply chain and operations from 2024 to 2029. The Investment Plan focuses on RD&E activities that maximise return on investment through operations and supply chain management. The specific objective of this investment plan is to identify priority elements that maybe enhanced through the introduction of technologies, or systems, to increase the performance of the supply chain, and broader forest operational activities.

The scope of the investment plan encompasses forest operations such as establishment and tending, harvest thinning and clearfall, extraction, in-forest processing and transport. It excludes operations inside the mill-gate. In the development of the investment plan, consideration has been given to previous research investment within this program, and other published research. Consultation with current operations staff within the industry has been given primacy to develop a clear understanding of contemporary needs.

The investment plan has considered the forest industry supply chain in terms of scale and value to ensure a sound basis for prioritising projects. The following summary offers some insight into the relativity of the different sectors and segments within each.

Figure ES1: Supply chain sector / segment value (2022)



Source: ABARES, industry datasets

Through direct communications with industry representatives, consideration of the range of potential topics at a workshop and subsequent review of the priority list, a shortlist of areas the industry considers worthy of investment has been developed. A further series of topics were considered by industry, however, have not been shortlisted primarily due to there being a reasonable level of operational data / industry knowledge to assist decision making already, or the need being relevant for relatively few growers.

The shortlisted themes are tabled below. Four groups represent macro-segments, with a fifth considering issues relevant to the full supply chain.

Table ES1: Research theme - summary

Group	Theme	Priority	Context
1. **Harvesting**	Harvesting productivity	Medium	Technology to improve productivity of harvesting through automation
		Medium	Technology to improve productivity of harvesting using operator aids (Human-Machine Interaction), enhanced training systems and reviewing best practice methods
		High	Improved silvicultural outcomes through application of technologies to assist harvest machine operator tree selection, and track location.
	Industry skills	Medium / Low	Benchmarking operator performance and identifying state-of-the-art training systems to improve productivity for new and existing operators
	Machinery fuels	Medium	Current innovations regarding alternative fuels, applicability in Aus settings and potential constraints
	Log stock management	High	Log stock management systems, status of technological solutions and impediments to implementation
	Forest infrastructure	High	Options for extending wet weather harvesting via road engineering or mechanical solutions. Technologies for assessing road surface depth, strength and durability.
		Low	Resilience of current infrastructure and regulatory prescriptions to future extreme weather events.
2. Residues	Residue economics	Medium	Current status and developing technologies in relation to end-uses, extraction and processing options, value and costs
3. Transport	Transport productivity	Low	Potential for semi-autonomous trucks in an off-road setting
		Medium	Higher payloads and pathway for regulatory approval in Aus settings
	Transport fuels	Medium	Technologies with the potential to reduce emissions in transport
4. Plantation Operations	Productivity – automation and robotics	High	Application of mechanical planting technology across Aus operating environments.
5. General	Knowledge management	High	Improved access to previous research
		High	Better transfer of knowledge and adoption
	Reporting	Low	Emissions reporting requirements and opportunities for better reporting to incentivise innovative solutions

The themes and associated problem statements are tabled below, with various attribution to support prioritisation. This encompasses the value of the supply chain segment (nationally), the potential realisation period for any research benefits, the benefit type and the scale of any research investment.

Further scoping for each area will be required prior to seeking any research provision to ensure sufficient detail is captured, deliverables are clearly defined, impacts can be assessed, and any complimentary work being undertaken either recently or concurrently can be adequately considered.

The following table provides the rating categories used in the supply chain classification and attribution process.

Table ES2: Supply chain class

Supply chain segments
Cut-to-length (roadside)
Cut-to-length (stump)
In-field Chip
Transport
Establishment

Table ES3 Value class

Segment value	Value class
<$80m	Low
$80m - $150m	Mod
$150m - $200m	High
>$200m	Very High

Table ES4: Research topic attributions

Benefits type	Realisation period	Project scale / cost
Costs	3+ Years	Low $50K
Revenue (Rev)	2 Years	Mod $100K
Productivity	1 Year	High $250K
Safety	<12 Months	
Environment		
Skills / Capability		
General		

Table ES5: Priority Research Areas

Theme	Priority	Context	Problem Statement	Segment	Segment Value	Real. Period	Benefit Type	Scale
Harvesting productivity	High	Improved silvicultural outcomes through application of technologies to assist harvest machine operator tree selection, and track location.	Optimal silvicultural outcomes via production thinning are only achievable through intensive management by forest growers – tree marking or field QC. What technologies can be readily implemented to assist harvester operators improve tree selection at thinning and/or for forest growers to monitor outcomes - stand density management as a priority? Can the 'digital twin' concept solve this problem?	CTL Stump	Very High	3+ Years	Rev	Mod
			Benchmark – Current cost of tree marking. Proportion of crop trees removed at thinning. Potential impact – reduction in tree marking costs, improved safety outcomes, uplift in stand value arising from better tree selection					

Theme	Priority	Context	Problem Statement	Segment	Segment Value	Real. Period	Benefit Type	Scale
	High		The number and position of outrows and extraction tracks can be dictated by machine limitations and safe use. This can have a significant impact on the value of the final crop. What technologies can be adapted to (i) assist with the location of new outrows and extraction tracks (at establishment or pre-T1), and then (ii) record precise location of outrows removed to aid future planting?	CTL Stump	Very High	2 Years	Rev	Low
			Benchmark – Current cost of tree marking (tracking), current final crop trees removed at thinning Potential impact – reduced number of potential final crop trees removed at thinning, reduced cost					
	Medium	Technology to improve productivity of harvesting through automation	Supply chain productivity continues to remain stagnant. Can the use of autonomous equipment in harvest operations deliver real productivity / efficiency gains?	Harvest - all	Very High	3+ Years	Prod'ty	Mod
			Benchmark – average harvest cost, production volume per FTE Potential impact – higher productivity, reduced costs					
	Medium	Technology to improve productivity of harvesting using operator aids (Human-Machine Interaction) , enhanced training systems and reviewing best practice methods	Supply chain productivity continues to remain stagnant. What tools / systems are available to make harvesting more fuel-efficient, economic and productive? (e.g. Intelligent boom systems, forward felling approaches, squirt booms)	CTL Stump	Very High	3+ Years	Prod'ty	Mod
			Benchmark – average harvest cost Potential impact – higher machine productivity, reduced operator fatigue					
	Medium	Investigate technologies to reduce the risk of harm to koalas and reduce compliance costs	The cost of implementing measures to protect koalas is significant. What additional technologies can be implemented to reduce the risk of harming koalas and reduce the cost of koala detection in hardwood and softwood plantations?	Hardwood Plantation - Harvest	Very High	2 Years	Enviro	Low
			Benchmark – animal incidents per year. Cost of compliance per gmt. Potential impact – reduction in injured animals, lower cost of compliance					

Theme	Priority	Context	Problem Statement	Segment	Segment Value	Real. Period	Benefit Type	Scale
Industry skills	Medium / Low	Benchmarking operator performance and identifying state-of-the-art training systems to improve productivity for new and existing operators	Operators are hard to find, expensive to train, easily lost. Can training methods be improved to ensure new and existing operators are more productive?	Harvest - all	Very High	3+ Years	Skills / Capability	Low
			Benchmark – volume harvested per operator FTE Potential impact – improved operator performance, higher productivity, earlier adoption of technologies					
Machinery fuels	Medium	Current innovations regarding alternative fuels, applicability in Aus settings and potential constraints	The industry continues to seek opportunities to meet emissions reduction targets. What technologies are likely to be available to assist with emissions reduction from harvesting systems? What are the potential infrastructure considerations for each technology? What are the risks of mandated standards to the industry over the next 5 to 10 years?	Harvest - all	Very High	3+ Years	Enviro	Mod
			Benchmark – tCO2e per gmt of logs harvested Potential impact – minimise the cost of emissions reduction					
Log stock management	High	Log stock management systems, status of technological solutions and impediments to implementation	Growers have a good understanding of production via harvest head technology, and uplift at roadside from e-docketing. Can technologies / processes be implemented to improve estimates of in-bush and roadside log stock, and reduce the reliance on manual log stock calls?	Harvest - all	Very High	2 Years	Rev	Mod
			Benchmark – log stock reporting costs. Current truck utilisation losses associated with poor stock data. Potential impact – reduction in current cost of managing log stocks, improved transport efficiency through better log stock information					

Theme	Priority	Context	Problem Statement	Segment	Segment Value	Real. Period	Benefit Type	Scale
Forest infrastructure	High	Options for extending wet weather harvesting via road engineering or mechanical solutions. Technologies for assessing road surface depth, strength and durability.	Building and maintaining forestry roads is a significant expense. Areas available to seasonally balance operations are limited. What systems and technologies are available to improve the ability to harvest areas in wet weather? It can be difficult to find the right skills for planning, supervising and undertaking road works. Are there any existing or emerging technologies (e.g. sensing tech) to aid objective assessments of road surface depth and dimensions, to assist with efficient and effective planning, supervising and budgeting for road works?	Harvest - all	Very High	3+ Years	Enviro	Low
			Benchmark – current seasonality mix, all-weather harvest area roading costs Potential impact – improved seasonality of forest estates, optimisation of infrastructure budgets.					
	Low	Resilience of current infrastructure and regulatory prescriptions to future extreme weather events.	Climate change will result in the intensity and frequency of damaging weather events, including rain / wind storms. Will the existing controls/best practices for soil and water management be effective in the future (in relation to road/landing construction and maintenance, harvesting)? What cost-efficient technologies are available for replacing ageing / inadequate infrastructure?	Harvest - all	Very High	3+ Years	Enviro	Low
			Benchmark – TBD Potential impact – through early adaption, an overall reduction in environmental impacts and infrastructure costs.					
Residue economics	Medium	Current status and developing technologies in relation to end-uses, extraction and processing options, value and costs	Significant market interest continues to develop in the use of forest residues. Numerous studies have been conducted but growers are still lacking good operational specific data to support sound decisions. What are the most efficient means of residue extraction, storage and processing from different operating	Harvest - all	Very High	2 Years	Revenue	Low

Theme	Priority	Context	Problem Statement	Segment	Segment Value	Real. Period	Benefit Type	Scale
			environments and what are the likely costs? There is a need to better understand the types of materials likely to be in demand and the attributes to support marketing decisions.					
			Benchmark – TBD Potential impact – improved revenue, reduction in emissions, site establishment costs					
Transport productivity	Low	Potential for semi-autonomous trucks in an off-road setting	Productivity has been constrained in many operations due to a lack of suitable truck drivers. Can the industry reduce the reliance on drivers through semi-autonomous trucks? What are the potential productivity / efficiency gains?	Transport - all	Very High	3+ Years	Productivity	High
			Benchmark – volume transported per driver FTE Potential impact – productivity gains through driverless technology					
	Medium	Increased payloads and pathway for regulatory approval in Aus settings	Transport efficiencies continue to be achieved through higher payloads. How can the industry best achieve these gains? Increased application of zero tolerance for overloading has led to a decrease in average payloads. Are there better technologies available, and what are the implications for loading sites in order to improve the accuracy of truck scales.	Transport - all	Very High	2 Years	Prod'ty	Mod
			Benchmark – Average actual payload per existing truck configuration Potential impact – increased average actual payloads					
Transport fuels	Medium	Technologies with the potential to reduce emissions in transport	Transport comprises 50% of raw material costs. What options are available and practical to remove the volatility and risk on this key part of the transport sector relying on fossil fuels? What technologies are likely to be available to assist with emissions reduction in log transport? What are the potential infrastructure considerations for each technology?	Transport - all	Very High	3+ Years	Environment	High
			Benchmark – tCO2e per gmt of logs delivered Potential impact – Reduction in emissions, mitigation of costs associated with reduced emissions					

Theme	Priority	Context	Problem Statement	Segment	Segment Value	Real. Period	Benefit Type	Scale
Productivity - automation and robotics	High	Application of mechanical planting technology across Aus operating environments.	Hand planting continues to be high risk activity and potentially constrained by available resources. What developments are occurring elsewhere and how can the Australian plantation sector expedite the development and adoption of effective and cost-efficient technologies across the range operating environments? Is there potential for autonomous robotic solutions?	Estab	Very High	3+ Years	Costs	High
Knowledge management	High	Improved access to previous research, and better transfer of knowledge and adoption	Recent research outcomes are not easy to find, traditional means of transferring knowledge may not always be appropriate, and research findings are rarely adopted at any scale. Can improvements be made to online access, increased expectations regarding communication and extension in research proposals and deeper engagement and collaboration within industry to evaluate best-practice.	All	Very High	<12 Months	Skills / Capability	Low
			Benchmark – NA Potential impact – More efficient and timely adoption of research findings and endurance of changed practices					
Reporting	Low	Emissions reporting requirements and opportunities for better reporting to incentivise innovative solutions	Reporting emissions is currently done at a high level. How can the granularity and precision of estimates be improved in an efficient way including a range of parameters such as carbon and particulates? How reporting and managing emissions be used to encourage innovation and adaption?					
			Benchmark – TBD Potential impact – reduced cost of reporting and earlier adoption of new technologies					

Contents

1 Background

FWPA is one of 15 rural research and development corporations responsible for managing funds levied from the relevant rural primary and secondary industries, along with government funds to deliver priority research, development and extension (RD&E) activities relevant to the forest and wood products sector.

The current FWPA Strategic Plan (2023-2028) encapsulates the following links to forest operations and supply chain research.

Vision	*The Australian forest and wood products industry will grow in value as a result of increased demand for its innovative, sustainable and competitive products and services.*
Mission	*FWPA collaborates with government and industry to deliver transformative RD&E initiatives and market development programs to drive growth in the Australian forest and wood products industry.*
Outcome Number 3	*Growers and processors - Improve the resource base, reduce risk and increase productivity and utilisation along the value chain*
Objectives	➢ *Increase estate productivity and reduce the risk for forest growers* ➢ *Optimise the forest to finished wood product value chain:* ○ *optimise data sharing* ○ *maximise the use of the sector's by-products* ➢ *Develop new tools for resource grading standards* ➢ *Support the monetisation of carbon and other ecosystem services*

FWPA Grower Research Advisory Committee (GRAC) - objective is to double the value of Australia's commercial forests by 2040. It has nine investment plans in place.

- Minimise threats from damage agents,
- Priorities to achieve value gains through management of plantation nutrition,
- Priorities to achieve value gains through Plantation Silviculture,
- Minimise the impacts of fire on Australia's commercial forest estate,
- Priorities for sustainable value gains through Tree Breeding & Genetic Improvement
- Priorities to achieve value gains through forest resource modelling and remote sensing,
- Priorities for native forest silviculture,
- Beneficial soil microbiome- tree interactions in nursery and forest settings, and this;
- **Forest operations and supply chain management research, development and extension priorities.**

FWPA's Operations and Supply Chain Investment Plan, released in 2020, identified opportunities for progressing the GRAC Vision through investments in RD&E that reduce operational costs and increase product volume and value recovery for the industry.

In mid-2022 FWPA commissioned a high-level review of the Investment Plan priorities as part of a broader review of the operations and supply chain research program, based on consultation with key industry stakeholders. A key recommendation of that review was to undertake a deeper engagement

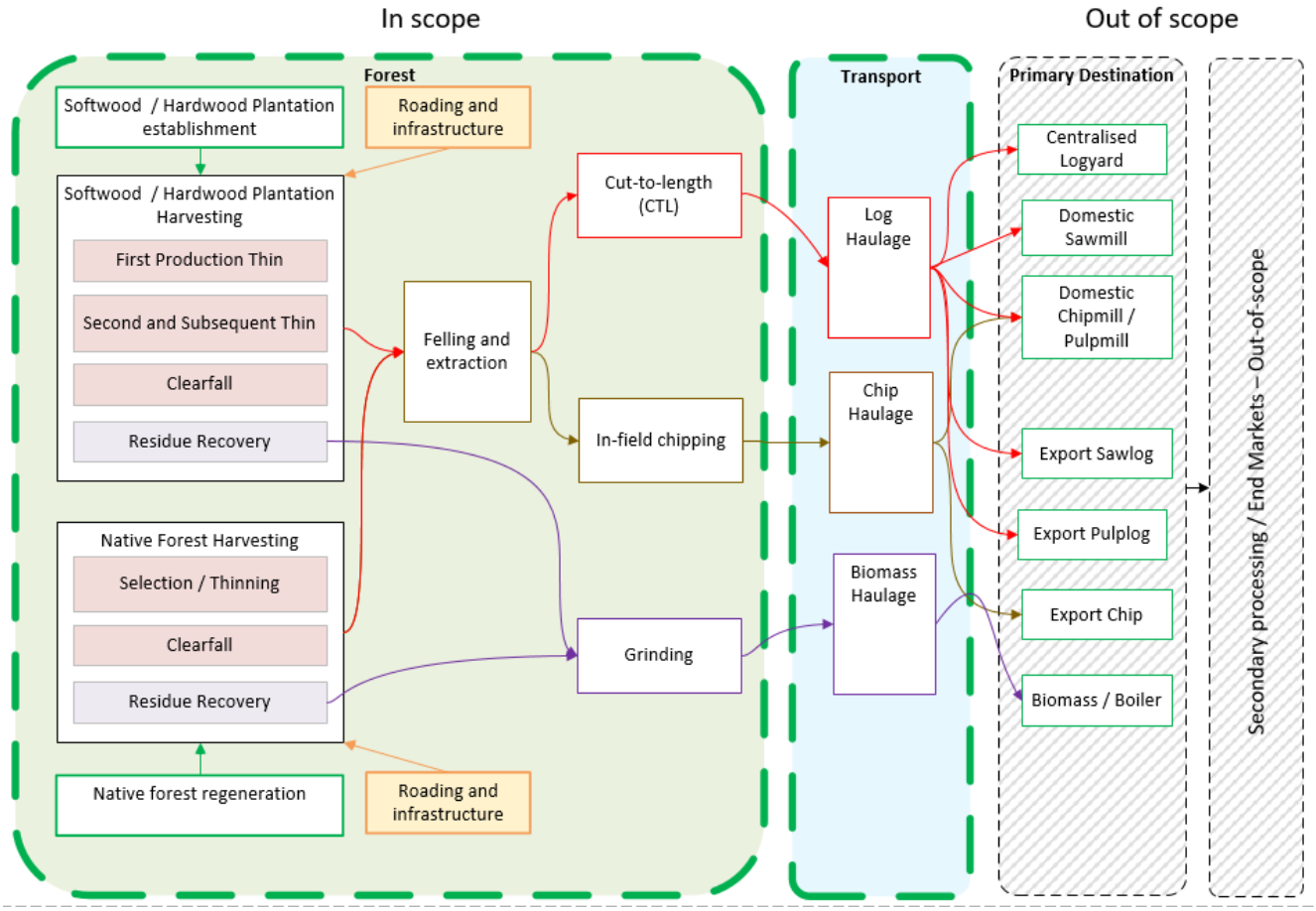
with industry to ensure research was directed into projects that were seen more broadly as high priority. This investment plan has been developed within the context of that review.

2 Objectives and scope

This Investment Plan establishes a blueprint for RD&E investment for the Australian forestry sector in the supply chain and operations from 2024 to 2029. The Investment Plan focuses on RD&E activities that maximise return on investment through operations and supply chain management. The specific objective of this investment plan is to identify elements that maybe enhanced through the introduction of technologies, or systems to increase the performance of the supply chain, and broader forest operational activities.

The scope of the investment plan encompasses forest operations such as establishment and tending, thinning to waste, harvest thinning and clearfall, extraction, in-forest processing and transport. It excludes operations inside the mill-gate.

Figure 2-1: Conceptual view of the supply chain and scope of this investment plan



In the development of the investment plan, consideration has been given to previous research investment within this program, published research undertaken through previous Forestry CRC's, NIFPI's as well as a high-level review of international programs. Consultation with current operations staff within the industry has been given primacy to support a clear understanding of contemporary needs.

3 Supply chain analysis

The investment plan has considered (at a relatively high level) the forest industry supply chain in terms of scale and value to ensure a sound basis for prioritising projects. The following summary offers some insight into the relativity of the different sectors and segments within each.

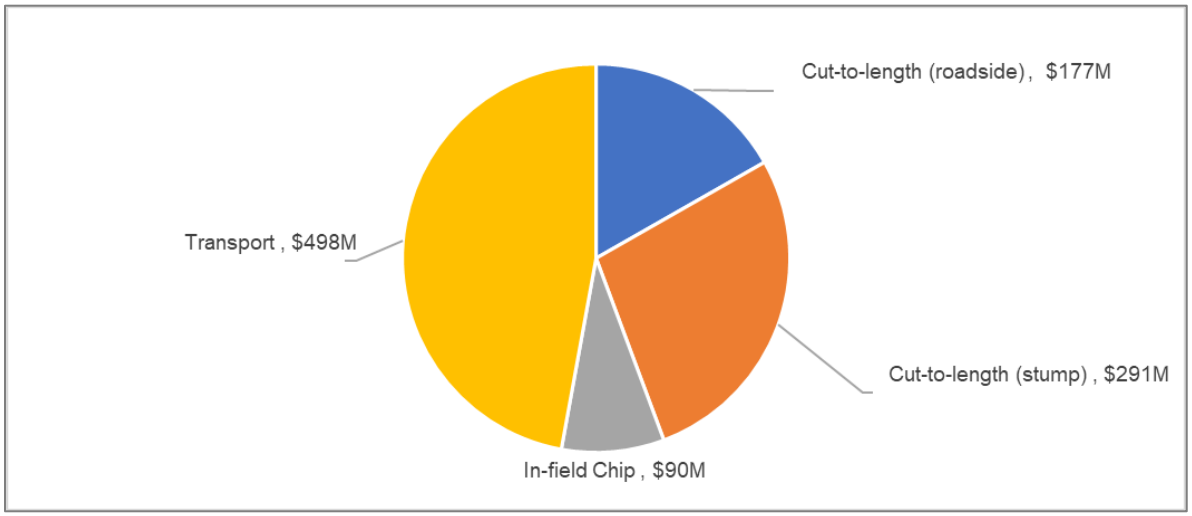
Table 3-1: Volume harvested by sector (2022)

Sector	'000 m³
Hardwood native	3 357
Hardwood plantation	7 702
Softwood	14 924
Total	25 983

Source: ABARES[1]

Based on ABARES Forest Industry statistics (gross value of log production) an estimate of average supply chain costs has been established. Figure 3-1 provides an indication of the industry value by segment, with transport representing approximately half of the total expenditure by forest growers, whilst cut-to-length operations dominate the harvesting component.

Figure 3-1: Supply chain segment value ($M, 2022)



Source: ABARES[1, 2], industry datasets

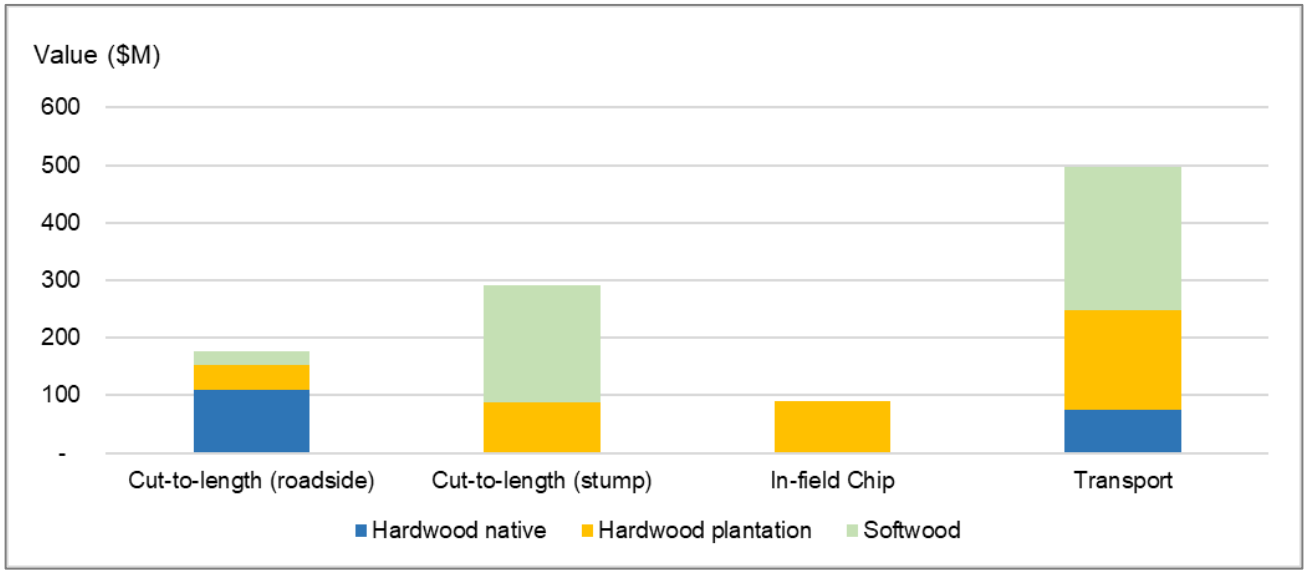
[1] ABARES 2023, Australian forest and wood products statistics: September and December quarters 2022, ABARES research report 23.13, Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra, June, DOI https://doi.org/10.25814/7ske-0873. CC BY 4.0.

[2] Lock, P, 2022, The Forest Resource Use Model (FoRUM): A spatial-temporal model of Australia's forest industry, ABARES, Canberra, October, DOI: https://doi.org/10.25814/txbe-eg61 CC BY 4.0.

Note: Cut-to-length operations have been categorised into ‘at stump’ and ‘at roadside’ to distinguish between short length and tree length extraction.

This is further broken down within each sector in Figure 3-2 below. Softwood plantations represent around 50% of the transport value, and the majority of the cut-to-length harvesting value.

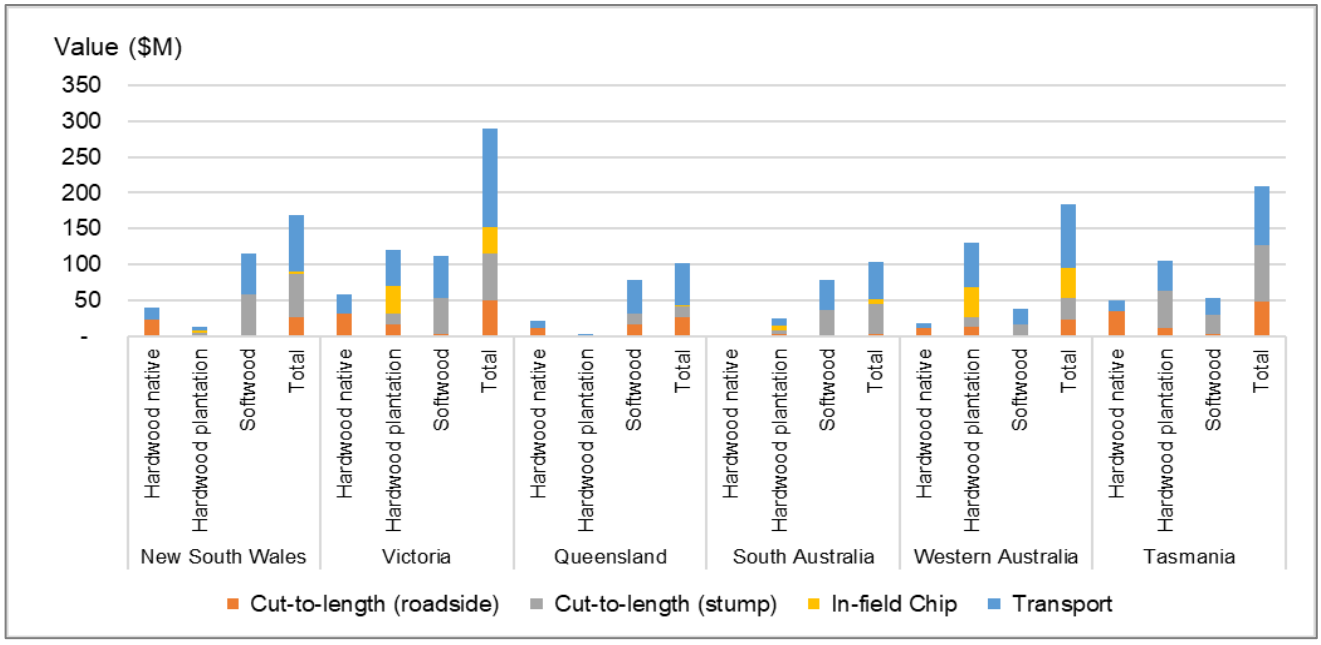
Figure 3-2: Supply chain sector / segment value (2022)



Source: ABARES[1, 2], industry datasets

Broken down further by state, it is evident that (at least in 2022) the Victorian industry was significantly more active than any other state, distributed across the hardwood and softwood plantation and native forest sectors. (see Figure 3-3 below).

Figure 3-3: Supply chain sector / segment value by state (2022)



Source: ABARES[1,2], industry datasets

This analysis is incorporated into the evaluation of priorities for this investment plan.

4 Methodology

A review of FWPA's 2020 *Investment Plan Forest operations and supply chain management research, development and extension priorities,* commissioned during 2022, as well as current investment plans within other research streams informed the approach to developing this investment plan.

An expert review group was established to assist the author with identifying suitable methods for industry consultation, and a review of potential research topics and associated priorities.

A desktop review was undertaken to develop a reference list for current and recently completed research relevant to the scope of this program. This was used to assist the discussions with industry and to assist with finalisation of the priority list.

The investment plan was finalised through;

- Initial engagement with growers to compile a key contact list
- Email and follow up one-on-one conversations with key industry personnel
- The development of a longlist of potential research areas of interest
- A high-level review of current and recent research programs and available reports
- A workshop with industry representatives to explore areas of interest and consider a high-level prioritisation
- Follow up email consultation to confirm problem statements and priorities

  To facilitate the categorisation of potential research themes and topics, the following logical areas or groups within the supply chain were identified: harvesting, residues, transport, plantation operations, and a general classification that relates to all parts of the supply chain.

  Each identified topic was then assigned various attributes to assist with prioritisation – these related to supply chain segment value, the type of benefits to be generated, the potential time period to realising any gains, and the potential cost of undertaking each project. Note, for the purposes of this exercise, this was a high-level analysis only. This is discussed in detail in Section 6.2.

- The development of a priority shortlist for consideration by GRAC
- Finalisation of the investment plan encompassing the priority shortlist, lower ranked areas of interest and recommendations regarding knowledge management and market approaches

It is noted that further industry consultation will be required as part of development of any research proposals to ensure appropriate scoping and that sufficient detail is captured, deliverables are clearly defined, impacts can be assessed, and any complimentary work being undertaken either recently or concurrently can be adequately considered.

5 Current state of RD&E

A desktop review of recent and relevant research projects was conducted to assist with the consultation process and prioritisation of potential new areas of focus. Significant operations research encompassing forest supply chains continues to be undertaken in NZ, Europe, and North America.

For full details refer to Appendix 2 – List of relevant and recent research projects.

Summary of recent research relevant to forest operations in the Australian context includes;

- Sensor technology for improved value recovery scanners
- Testing automated measurement of in-supply chain inventory and key supply chain infrastructure performance
- Various biomass / bioenergy projects through the IEA Bioenergy group and ARC for Forest Value
- Improved safety through wearable sensors , protective guarding and fatigue management best practice
- Optimal machine configuration for small-scale plantations and hardwood short log operations
- Managing moisture content in the supply chain
- Managing congestion at bulk cargo terminals

The AFORA Group published 32 Research Bulletins from 2008 – 2012 covering areas such as;

- Biomass recovery from softwood and low yielding hardwood plantations
- Transport scheduling optimisation and fuel consumption benchmarking
- Harvester mounted acoustic sensors
- Harvesting optimisation systems
- Machine productivity, chipping operations and volume recovery comparisons in hardwood plantations
- Tare weights and transport efficiency

Specific research that is relevant to each of the themes identified in Section 7 are referenced under each theme.

6 Assessment of priorities and potential impacts

The Council of Rural Research and Development Corporations (2014) (CRRDC) provides a framework for assessing the impact of RDC research projects and programs based on the established techniques of benefit-cost (BCA) analysis. The framework promotes a focus on project outcomes and benefits, purpose and expected outcomes, with the intent to focus on research objectives and how the proposed research will achieve them. In order to measure operational and supply chain efficiency gains, benchmarks must be defined against which those gains can be realised.

This investment plan provides suggested means of establishing benchmarks for each theme, and points to potential impacts that may be quantified. It would be anticipated that these would be explored and defined in more detail as proposals for each research topic are developed.

As the investment plan demands some structured means of determining research priorities, this section provides an indication of the parameters applied to each area of interest raised through the consultation process. These could form the basis of developing specific impacts for each detailed proposal.

6.1 Supply Chain segment value

Each segment of the supply chain was valued using the methodology described in Section 3. This can be used as a factor in determining the priorities and potential impacts of any research topics. The table below provides a relative assessment for each individual and aggregated segment.

Table 6-1: Supply chain segment valuation

Segment	Value ($million)	Value of each % gain ($million)	Segment value rating
Native - CTL Roadside	110	11	Mod
Native - Harvest	110	11	Mod
Native - Transport	76	8	Low
Hardwood Plantation - CTL Roadside	43	4	Low
Hardwood Plantation - CTL Stump	89	9	Mod
Hardwood Plantation - Chip	90	9	Mod
Hardwood Plantation - Harvest	223	22	Very High
Hardwood Plantation - Transport	171	17	High
Softwood Plantation - CTL Roadside	24	2	Low
Softwood Plantation - CTL Stump	202	20	Very High
Softwood Plantation - Chip	-	-	Low
Softwood Plantation - Harvest	226	23	Very High
Softwood Plantation - Transport	250	25	Very High
CTL Roadside - all	177	18	High
CTL Stump - all	291	29	Very High
Harvesting - all	558	56	Very High

Segment	Value ($million)	Value of each % gain ($million)	Segment value rating
In-Field Chipping - all	90	9	Mod
Transport - all	498	50	Very High
All	1 614	161	Very High
Native Regeneration	10	1	Low
Hardwood Plantation Establishment	66	7	High
Softwood Plantation Establishment	130	13	Very High
Establishment	205	21	Very High

6.2 Research topic attributes

Research topics / areas of interest have been further evaluated in terms of the types of benefits expected to be delivered, the potential timeframe within which any benefits might be realised, and the anticipated cost of the research project.

Table 6-2 provides the rating categories used in this attribution process.

Table 6-2: Research topic benefits type

Benefits type	Realisation period	Project scale / cost
Costs	3+ Years	Low $50K
Revenue	2 Years	Mod $100K
Productivity	1 Year	High $250K
Safety	<12 Months	
Environment		
Skills / Capability		
General		

7 RD&E Needs 2023 - 2028

Through direct communications with industry representatives, consideration of the range of potential topics at the Melbourne Workshop and subsequent review of the priority list, the following needs have been tabled based on low, medium, and high priority. A further series of topics were considered by industry, however, have not been shortlisted primarily due to there being a reasonable level of operational data / industry knowledge to assist decision making already.

A full list of research areas is tabled in Appendix 3. The shortlisted themes are tabled below. Four groups represent macro-segments, with a fifth considering issues relevant to the full supply chain.

Table 7-1: Research theme - summary

Group	Theme	Priority	Context
1. **Harvesting**	Harvesting productivity	Medium	Technology to improve productivity of harvesting through automation
		Medium	Technology to improve productivity of harvesting using operator aids, combined with enhanced training systems (see below) and reviewing best practice
		High	Improved silvicultural outcomes through application of technologies to assist harvest machine operator tree selection, and track location.
	Industry skills	Medium / Low	Benchmarking operator performance and identifying state-of-the-art training systems to improve productivity for new and existing operators
	Machinery fuels	Medium	Current innovations regarding alternative fuels, applicability in Aus settings and potential constraints
	Log stock management	High	Log stock management systems, status of technological solutions and impediments to implementation
	Forest infrastructure	High	Options for extending wet weather harvesting via road engineering or mechanical solutions. Technologies for assessing road surface depth, strength and durability.
		Low	Resilience of current infrastructure and regulatory prescriptions to future extreme weather events.
2. Residues	Residue economics	Medium	Current status and developing technologies in relation to end-uses, extraction and processing options, value and costs
3. Transport	Transport productivity	Low	Potential for semi-autonomous trucks in an off-road setting
		Medium	Higher payloads and pathway for regulatory approval in Aus settings
	Transport fuels	Medium	Technologies with the potential to reduce emissions in transport
4. Plantation Operations	Productivity – automation and robotics	High	Application of mechanical planting technology across Aus operating environments.
5. General	Knowledge management	High	Improved access to previous research
		High	Better transfer of knowledge and adoption
	Reporting	Low	Emissions reporting requirements and opportunities for better reporting to incentivise innovative solutions

A note on operational research

Numerous research topics that have been identified through the development of problem statements may not require primary research methods, as much of the innovation and technical knowledge has been established in other operating environments.

This is particularly relevant for Australian plantation harvesting operations, in that whilst around 20M tonnes is harvested annually, in Sweden and Finland around 160M tonnes is harvested, predominantly from similar cut-to-length operations with multiple thinning events. Therefore investment in research that fully leverages international experiences, new technologies and systems in other jurisdictions will deliver value gains more expediently.

It may be warranted therefore, to focus on projects that undertake a review of best practice / innovations in other jurisdictions, evaluate their applicability in local settings, and identify suitable pathways for delivery through appropriate extension activities.

Each of the themes are discussed in more detail below. It is noted that further industry consultation will be required as part of development of any research proposals to ensure appropriate scoping and that sufficient detail is captured, deliverables are clearly defined, impacts can be assessed, and any complimentary work being undertaken either recently or concurrently can be adequately considered.

7.1 Harvesting

Themes identified within harvesting operations include **productivity** and **industry skills**, **fuels**, **log stock** management and **infrastructure**. Whilst productivity and skills are closely related in many aspects, topics within the productivity theme would be largely machine and systems / methods focused, as opposed to the performance of the operators.

Autonomous machines and vehicles are increasingly prevalent in industries such as mining, agriculture, and road transportation. Automation is seen as a potential solution to a number of concerns within the forest industry, in terms of labour shortages, high turnover, safety and costs. However, more immediate improvements are likely to be gained through the adoption of new (and existing) operator aids, or augmentation. As an example, Skogforsk have a priority area of research in Human Machine Interaction (HMI) that is specifically addressing the load on machine operators. Together with a focus on logging methods and associated training courses, there is a coordinated approach to driving improvements in more fuel-efficient, economic and productive logging.

There is likely to be a spectrum of innovations and adoption from smaller technological solutions to assist operators undertake tasks more quickly as well as make better decisions, through to full automation is a long-term proposition.

Whilst training in Australia is largely focused on new operators and safety aspects, the industry believes that there is scope to improve the performance of all operators through a structured framework that draws on international experience particularly in Scandinavia. Research into appropriate training systems to manage industry skills is seen as a means of achieving an uplift in performance through improved techniques, and earlier adoption of the operator aids discussed above.

Achieving improved silvicultural outcomes, at a reduced cost through the application of technology is a high priority for the industry. Significant developments in machine technology are being brought into the market in terms of scanners to assist tree selection both from a tree density and tree quality perspective.

Whilst much of the innovation in harvesting technology is being delivered by the machine manufacturers primarily from Scandinavia, investment from the Australian sector in evaluating potential current and emerging solutions in the local context is a critical element in fast-tracking appropriate adoption of new systems. In this sense, the investment should be directed at:

i. Evaluating new and emerging solutions to the identified problem at a global scale
ii. Deep industry engagement to ensure any identified technologies have the potential to solve the problem
iii. Identifying any barriers to adoption and defining a suitable pathway

The cost of managing operations to avoid impact on koalas in hardwood (and increasingly softwood) plantations continues to be significant. Several projects have been or are being conducted into innovative detection techniques. Any projects must be developed to complement concurrent activities under other funding arrangements.

A detailed list of recent relevant research is listed in Appendix 2.There has been recent investment into koala detection, appropriate harvesting systems for hardwood short-log operations, harvesting on steep slopes, the benefits and management of harvesting head technology, and comparison of alternate harvesting systems in hardwood plantations. The proposed areas for investment do not appear to have been addressed, however a number of projects previously undertaken can provide useful context for new research.

Table 7-2: Research priority areas (harvesting)

Theme	Priority	Context Description	Problem Statement	Segment	Segment Value	Real. Period	Benefit Type	Scale
Harvesting productivity	High	Improved silvicultural outcomes through application of technologies to assist harvest machine operator tree selection, and track location.	Optimal silvicultural outcomes via production thinning are only achievable through intensive management by forest growers – tree marking or field QC. What technologies can be readily implemented to assist harvester operators improve tree selection at thinning and/or for forest growers to monitor outcomes - stand density management as a priority? Can the 'digital twin' concept solve this problem?	CTL Stump	Very High	3+ Years	Revenue	Mod
			Benchmark – Current cost of tree marking. Proportion of crop trees removed at thinning. Potential impact – reduction in tree marking costs, improved safety outcomes, uplift in stand value arising from better tree selection					
	High		The number and position of outrows and extraction tracks can be dictated by machine limitations and safe use. This can be a significant impact on the value of the final crop. What technologies can be adapted to (i) assist with the location of new outrows and extraction tracks (at establishment or pre-T1), and then (ii) record precise location of outrows removed to aid future planting?	CTL Stump	Very High	2 Years	Revenue	Low
			Benchmark – Current cost of tree marking (tracking), current final crop trees removed at thinning Potential impact – reduced number of potential final crop trees removed at thinning, reduced cost					
	Medium	Technology to improve productivity of harvesting through automation	Supply chain productivity continues to remain stagnant. Can the use of autonomous equipment in harvest operations deliver real productivity / efficiency gains?	Harvest - all	Very High	3+ Years	Prod'ty	Mod
			Benchmark – average harvest cost, production volume per FTE Potential impact – higher productivity, reduced costs					
	Medium	Technology to improve productivity of harvesting using operator aids (Human-Machine Interaction) , enhanced training	Supply chain productivity continues to remain stagnant. What tools / systems are available to make harvesting more fuel-efficient, economic and productive? (e.g. Intelligent boom systems, forward felling approaches, squirt booms)	CTL Stump	Very High	3+ Years	Prod'ty	Mod

Theme	Priority	Context Description	Problem Statement	Segment	Segment Value	Real. Period	Benefit Type	Scale
		systems and reviewing best practice	Benchmark – average harvest cost Potential impact – higher machine productivity, reduced operator fatigue					
	Medium	Investigate technologies to reduce the risk of harm to and reduce compliance costs	The cost of implementing measures to protect koalas is significant. What additional technologies can be implemented to reduce the risk of harming koalas and reduce the cost of koala detection in hardwood and softwood plantations?	Hardwood Plantation - Harvest	Very High	2 Years	Enviro	Low
			Benchmark – animal incidents per year. Cost of compliance per gmt. Potential impact – reduction in injured animals, lower cost of compliance					
Industry skills	Medium / Low	Benchmarking operator performance and identifying state-of-the-art training systems to improve productivity for new and existing operators	Operators are hard to find, expensive to train, easily lost. Can training systems be improved to ensure new and existing operators are more productive?	Harvest - all	Very High	3+ Years	Skills / Capability	Low
			Benchmark – volume harvested per operator FTE Potential impact – improved operator performance, higher productivity, earlier adoption of technologies					
Machinery fuels	Medium	Current innovations regarding alternative fuels, applicability in Aus settings and potential constraints	The industry continues to seek opportunities to meet emissions reduction targets. What technologies are likely to be available to assist with emissions reduction from harvesting systems? What are the potential infrastructure considerations for each technology? What are the risks of mandated standards to the industry over the next 5 to 10 years?	Harvest - all	Very High	3+ Years	Enviro	Mod
			Benchmark – tCO2e per gmt of logs harvested Potential impact – minimise the cost of emissions reduction					
Log stock management	High	Log stock management systems, status of technological solutions and impediments to implementation	Growers have a good understanding of production via harvest head technology, and uplift at roadside from e-docketing. Can technologies / processes be implemented to improve estimates of in-bush and roadside log stock, and reduce the reliance on manual log stock calls?	Harvest - all	Very High	2 Years	Rev	Mod
			Benchmark – log stock reporting costs. Current truck utilisation losses associated with poor stock data. Potential impact – reduction in current cost of managing log stocks, improved transport efficiency through better log stock information					

Theme	Priority	Context Description	Problem Statement	Segment	Segment Value	Real. Period	Benefit Type	Scale
Forest infrastructure	High	Options for extending wet weather harvesting via road engineering or mechanical solutions. Technologies for assessing road surface depth, strength and durability.	Building and maintaining forestry roads is a significant expense. Areas available to seasonally balance operations are limited. What systems and technologies are available to improve the ability to harvest areas in wet weather? It can be difficult to find the right skills for planning, supervising and undertaking road works. Are there any existing or emerging technologies (e.g. sensing tech) to aid objective assessments of road surface depth and dimensions, to assist with efficient and effective planning, supervising and budgeting for road works?	All	Very High	3+ Years	Enviro	Low
			Benchmark – current seasonality mix Potential impact – improved seasonality of forest estates, optimisation of infrastructure budgets.					
	Low	Resilience of current infrastructure and regulatory prescriptions to future extreme weather events.	Climate change will result in the intensity and frequency of damaging weather events, including rain / wind storms. Will the existing controls/best practices for soil and water management be effective in the future (in relation to road/landing construction and maintenance, harvesting)? What cost-efficient technologies are available for replacing ageing / inadequate infrastructure?	Harvest - all	Very High	3+ Years	Enviro	Low
			Benchmark – TBD Potential impact – through early adaption, an overall reduction in environmental impacts and infrastructure costs.					

7.2 Residues

Forest residues have been the subject of numerous contemporary research programs, most recently under the FWPA O&SC program via the IEA Bioenergy[3] Task 43 group. USC is the Operating Agent for IEA Bioenergy Task 43. It is exploring technical and economic strategies to increase the quantity of biomass available, improve the quality of biomass delivered for different energy purposes, and explore strategies to increase the value and confidence in supply of biomass for energy. This is currently considering biohub screening for improved biomass quality, biohub business models, consideration of site productivity impacts, and developing a better understanding of biomass characteristics.

The previous Forestry CRC considered harvesting techniques for low productivity hardwood plantations, bundling systems and options for 'fibre plus recovery, forwarding and chipping systems. The ARC Training Centre for Forest Value in Tasmania focused on supply chain models, and bioenergy generation in the local context.

The industry consultation for this investment plan demonstrated varied perspectives on the priorities for residues and biomass utilisation. Whilst some representatives indicated that much of the supply chain work had already been done, what was of interest was the likely end-uses, including the potential for micro-hubs for bioenergy generation and utilisation in-forest. Others felt that whilst some investment in evaluating biomass recovery operations had been previously undertaken, it was site specific and significant components of the plantation sector had not been sufficiently considered.

There is also a view that risks associated with higher levels of residue recovery must be given higher priority. This includes long term site productivity impacts, however there may also be implications for the recovery of higher value products. However, there was reasonable consensus that there is sufficient information available to manage these risks, and the onus was on forest growers to ensure that mitigation measures are in place.

In summary, the problem identified by the industry in relation to residues is reasonably general as tabled below. Forest growers may need to further evaluate the potential for the Task 43 program to deliver much of the research need, and the applicability of previous program findings to current issues. On this basis, further research under the O&SC program has been given a low priority.

[3] Technology Collaboration Programme (TCP) for a Programme of Research, Development and Demonstration on Bioenergy, functions within a Framework created by the International Energy Agency (IEA)

Table 7-3: Research priority areas (residues)

Theme	Priority	Context Description	Problem Statement	Segment	Segment Value	Real. Period	Benefit Type	Scale
Residue economics	Medium	Current status and developing technologies in relation to end-uses, extraction and processing options, value and costs	Significant market interest continues to develop in the use of forest residues. Numerous studies have been conducted but growers are still lacking good operational specific data to support sound decisions. What are the most efficient means of residue extraction, storage and processing from different operating environments and what are the likely costs? There is a need to better understand the types of materials likely to be in demand and the attributes to support marketing decisions.	Harvest - all	Very High	2 Years	Revenue	Low
			Benchmark – TBD Potential impact – improved revenue, reduction in emissions, site establishment costs					

7.3 Transport

As for harvesting, the industry has identified opportunities for improved productivity through the **automation** of trucks. This is being progressed particularly in Canada via the concept of truck platooning, whereby a lead truck coordinates a trailing fleet of driverless vehicles. It is most likely to have applicability on long haul routes via a non-public road network.

A shorter-term solution to achieving higher productivity is the pursuit of higher **payloads** for existing log truck configurations. There are potentially two avenues to explore.

- Firstly there has been (not universally) a reduction in average payloads for any given permissible configuration as the tolerance for overloading has largely been reduced under the Chain of Responsibility obligations emanating from the Heavy Vehicle National Law.

  Whilst the use of on-board truck scales has improved significantly in recent years, allowing a more accurate assessment of load weights in the forest, there is a tendency to underload if punitive measures are in place for overloading. Inaccurate in-forest weights arise due to poor equipment or inappropriate use and exacerbated by poor environments such as steep or uneven log loading sites. Research could investigate the extent to which this is a problem across different sectors within the industry, develop best practice guidelines for load scale equipment and operations, and quantify the benefits and costs of improved loading sites.

- A second area of investigation could be the truck combinations and associated permissible mass being achieved in other jurisdictions, particularly Scandinavia and North America. The project would explore the means by which regulatory approvals were achieved in each jurisdiction, to inform appropriate means of achieving similar approvals in Australian settings.

Emissions reduction is a key priority for the industry, both in terms of achieving better environmental outcomes and mitigating the costs of mandated standards. The cost of fuel is also highly variable, with consequential impacts on business cashflow and profitability. Reducing the reliance on fossil fuels has the potential to mitigate this volatility. The industry is motivated to explore what alternative fuels are available (including electric, hydrogen, hydrogenated vegetable oil), and the potential infrastructure considerations for each technology. Clearly much of this work is being undertaken in international settings and in larger industries. The research needs to focus on the options and implications specifically within the forestry setting.

Table 7-4: Research priority areas (transport)

Theme	Priority	Context Description	Problem Statement	Segment	Segment Value	Real. Period	Benefit Type	Scale
Transport productivity	Low	Potential for semi-autonomous trucks in an off-road setting	Productivity has been constrained in many operations due to a lack of suitable truck drivers. Can the industry reduce the reliance on drivers through semi-autonomous trucks? What are the potential productivity / efficiency gains?	Transport - all	Very High	3+ Years	Productivity	High
			Benchmark – volume transported per driver FTE Potential impact – productivity gains through driverless technology					
	Medium	Increased payloads and pathway for regulatory approval in Aus settings	Transport efficiencies continue to be achieved through higher payloads. How can the industry best achieve these gains? Increased application of zero tolerance for overloading has led to a decrease in average payloads. Are there better technologies available, and what are the implications for loading sites in order to improve the accuracy of truck scales.	Transport - all	Very High	2 Years	Prod'ty	Mod
			Benchmark – Average payload per configuration Potential impact – increased payloads for existing truck configurations					
Transport fuels	Medium	Technologies with the potential to reduce emissions in transport	Transport comprises 50% of raw material costs. What options are available and practical to remove the volatility and risk on this key part of the transport sector relying on fossil fuels? What technologies are likely to be available to assist with emissions reduction in log transport? What are the potential infrastructure considerations for each technology?	Transport - all	Very High	3+ Years	Environment	High
			Benchmark – tCO2e per gmt of logs delivered Reduction in emissions, mitigation of costs associated with reduced emissions					

7.4 Plantation operations / establishment

Whist much of the industry consultation focused on harvesting and haulage systems, the opportunities for reducing the manual labour component of planting is a priority for the industry. **Mechanical planting** has been developed in various forms since the 1970's, however no efficient means has yet been adopted that achieves the planting standards desired by industry across the range of operating environments typically encountered.

There has been significant progress recently by PlantMa AB[4], whilst other options are potentially worthy of further investigation.

A primary consideration of specialised mechanical planting equipment is the relatively short season available for utilisation. This will have consequential impacts on the effective use of capital. The capacity to utilise other equipment that can be used for multiple purposes over a year would be a means of diffusing these capital costs.

Additional benefits from mechanical planting such as the geolocation of seedlings could be explored to facilitate the implementation of precision forestry (i.e. leveraging technologies to collect and utilise data, to optimize forest management practices).

Based on international progress in relation to mechanical planting solutions, the Australian industry does not consider new technology requires research, but the evaluation of current developments and the potential for application across the range of operating environments in Australia.

[4] https://plantmaforestry.com/what-is-plantma-x/

Table 7-5: Research priority areas (plantation operations)

Theme	Priority	Context Description	Problem Statement	Segment	Segment Value	Real. Period	Benefit Type	Scale
Productivity - automation and robotics	High	Application of mechanical planting technology across Aus operating environments.	Hand planting continues to be high risk activity and potentially constrained by available resources. What developments are occurring elsewhere and how can the Australian plantation sector expedite the development and adoption of effective and cost-efficient technologies across the range operating environments? Is there potential for autonomous robotic solutions?	Estab'ent	Very High	3+ Years	Costs	High
			Benchmark – Planting cost per hectare, Number seedlings planted per FTE Potential impact – improved safety outcomes, reduction in planting costs, improved planting quality					

7.5 General

During the consultation phase of this investment plan, the issue of **knowledge management** was prominent in many discussions within the industry. Specifically, there was the concern that the findings of previous research and best practice are not well communicated, are not easily retrievable, nor in a form that is easily absorbed by operational staff. Some of the preferred outcomes identified by the industry stakeholders include;

- Ensuring findings from previous projects are able to be accessed easily, preferably through an enduring portal, potentially hosted by FWPA
- New projects have a clear expectation around the way findings will be communicated and the type of media to be used. It is accepted that for many types of potential projects traditional scientific papers are not appropriate to ensure an efficient transfer of knowledge.
- The level at which extension services are offered as part of the project need to be defined.
- Industry research could include short study tours by industry representatives to identify innovative solutions for adoption in local settings. This could include cross-industry collaboration and mentoring where study tours are funded as part of this investment plan.

It is also accepted that forest companies must maintain sufficient technical expertise to successfully implement change and innovation at an enterprise level.

A further area of interest are **emissions reporting systems,** as a response to investor demands and to identify suitable pathways for emissions reduction. At present, emissions are largely based on a high-level view of fuel consumption. This does may not always provide an accurate view, nor provide a framework that incentivises specific enterprises to reduce emissions.

Table 7-6: Research priority areas (general)

Theme	Priority	Context Description	Problem Statement	Segment	Segment Value	Real. Period	Benefit Type	Scale
Knowledge management	High	Improved access to previous research, and better transfer of knowledge and adoption	Recent research outcomes are not easy to find, traditional means of transferring knowledge may not always be appropriate, and research findings are rarely adopted at any scale. Can improvements be made to online access, increased expectations regarding communication and extension in research proposals and deeper engagement and collaboration within industry to evaluate best-practice.	All	Very High	<12 Months	Skills / Capability	Low
			Benchmark – NA Potential impact – More efficient and timely adoption of research findings and endurance of changed practices					
Reporting	Low	Emissions reporting requirements and opportunities for better reporting to incentivise innovative solutions	Reporting emissions is currently done at a high level. How can the granularity and precision of estimates be improved in an efficient way including a range of parameters such as carbon and particulates? How reporting and managing emissions be used to encourage innovation and adaption?	All	Very High	2 Years	Environment	High
			Benchmark – TBD Potential impact – reduced cost of reporting and earlier adoption of new technologies					

8 Funding allocations

Funding allocations should be based on the ranked importance of the themes and the commercial relevance to the industry. Priorities allocated in this investment plan have been derived through industry consultation, and an assessment of the supply chain segment value, benefits type, potential realisation period and scale of the project.

This process could be enhanced by further quantification of the potential impacts of each topic, using the suggested benchmarks and potential impact criteria tabled in Section 7. This is intended to ensure that operations and supply chain RD&E investment is aligned with FWPA levy payers' priorities.

Research projects should focus on working collaboratively across research and commercial organisations to maximise the value of the FWPA funding available.

Appendix 1 – Consultation

Stakeholders engaged

Name	Organisation	Name	Organisation
Simon Penfold	AMA, Landari	Mike Sutton	FCNSW
Simon Gatt	AKD Softwoods	Duncan Watt	FCNSW
Lou Coutts	HVP Plantations	Ross Dickson	FCNSW
Mark Howe	HVP Plantations	Ian Last	HQPlantations Pty Ltd
Brendan Piazza	HVP Plantations	Ockert Le Roux	OneFortyOne
Rob Hescock	HVP Plantations	Cameron MacDonald	OneFortyOne
Sharon Occhipinti	HVP Plantations	Ben Roberts	Forico
Darren Herd	Forico	Jake Lazarus	SCF
Heath Blair	Reliance Forest Fibre	Mark Brown	USC
Wayne Millard	Australian Bluegum Plantations	Sheryl Vickery	OneFortyOne
Alistair Hayward	SFM	Wendy Fennell	Fennell Forestry
Andrew Plank	SFM	Ricky Leeson	Leeson's Logging
Tim Benny	PF Olsen Australia		
Tammy Auld	Timberlands Pacific	Subject Matter Experts	
Jim Knott	Timberlands Pacific	Laurie Hein	MC Advisory
		Phil Stelling	
		Ian Wilson	ForestPHD
		Jeremy Gibson	ForestPHD

Workshop 6/8/2023

Participants:

Name (in person)	Organisation	Name (online)	Organisation
Damien O'Reilly	Mayday Consulting		
Jodie Mason	FWPA	Jim Knott	TPPL
Janette Newport	FWPA	Duncan Watt	FCNSW
Brendan Piazza	HVP	Laurie Hein	Ex GTFP EWG
Sharon Occhipinti	HVP	Ian Last	HQP
Mark Brown	Uni Sunshine Coast		
Heath Blair	Reliance Forest Fibre		
Wayne Millard	ABP		
Ben Roberts	Forico		

Investment Plan Background

The initial set of eight FWPA Investment Plans were developed in 2019, and Forest Operations and Supply Chain was one of these. The entire suite of investment plans was then collectively evaluated, and the proportion of investment allocated to each investment plan determined. This information was then used to support a proposal for an increase in levies. This increase is now in effect, significantly increasing the RD & E budget. Four of the plans are under review in 2023, and two reviews have been completed in 2022. One new investment plan (climate change) is also under development.

General discussion

The objective of this process is to maximise the best value of research investment to the industry at large by creating clear view of operations and supply chain current research needs and a level of prioritisation for broader review. Issues include - Value and volume actual vs inventory can be as much as +/- $4k per ha difference. Operators override of harvesting optimisation can have a significant negative impact on returns. Thinning in particular is a high-risk activity which has consequences for the whole rotation and value lost. Moisture content optimisers can significantly reduce haulage and fuel costs.

What are current challenges? What do we need to focus on to extract efficiencies and be broadly applicable across the industry? The increase in available funding has allowed for this review to include some blue sky thinking, while being cognisant of not repeating past work and building on existing knowledge. The current investment plan contains a long list of what people are considering as priority topics. This review will consolidate this thinking then synthesise them into broad themes. In the process, ideally benchmark where the industry is at and to be able to quantify potential improvements. Challenges lie in defining the scope of operations and supply chain research. FWPA is already constrained by what sort of research it can invest in that attract commonwealth co-funding. Non-RD&E projects can be parked and maybe able to be covered by other FWPA funding sources of investment i.e. research vs consulting. In general, RD & E must serve multiple interests which means that it needs to have broad appeal. If not, it would be considered more of a consulting role.

Reference to recent / current relevant projects

Examples of research projects from University of Sunshine Coast (Mark Brown)

Uni SC website – bulletins with all past research.

Example: Advances real time measurement s to increase value recovery.

Value difference heat map. Highly dependent on operator overriding optimal decisions, and reliance on individual operator decisions.

Variability depends on stump height, market conditions,

Linkages to other projects

Example: Moisture content PLAN wood and biomass supply chain optimisation

This is a strong logistics model i.e., avoiding carting water. Important in informing transport and harvesting decisions i.e., fuel savings, transport of biomass material, can be integrated with individual

company business models. Not complicated can deliver basic results. But could be customised to a specific requirement or challenge.

Example: Automated volumetric measurement of truckloads.

Reconstructing 2D picture to optimal staking into 3D. Scope to take this camera technology to get accurate volumes of stacked timber. multiple images and algorithms to construct optimal transport.

Example: Supply chain value optimisation program

3D representation imagining derived from Lidar train deep learning (TDL). Could illuminate operator decisions on stem size, stem form, branch angle. Ability to apply knowledge to trees in close proximity. Collaboration with overseas operations. More detail required around stem form of Aus and NZ growth. Thinning is a critical point of vulnerability for forest growers. Accuracy of sensors increasing all the time

Example: Tag, track and trace & connectivity of the supply chain

- Physically stamping the log.
- Image could not be reliably read.
- Shape, thickness of bark means that logs can be individually recognise (no need to tag)
- More suited to low volumes high value products

Examples from SE Queensland forestry hub projects:

- New harvesting technologies
- Biomass recovery (slip on slip off) – cost quality, moisture content.
- Suitable remote sensing technologies
- Harvester head data planning tool
- Harvest/haulage planning tools at tactical level

Other projects

- Cable yarder
- Advanced log and woodchip export supply chain management
- Mechanical fuel load reduction
- Australian biomass for bioenergy assessment
- Web based dashboard

Supply chain description / relative value

The industry is highly valuable and therefore a large appetite for potential for investment in RD &E that will improve efficiencies.

- Native $3.3M
- Hardwood plantation $7.7 M
- Softwood $14.9M
- Total $25.9 M

Broad program priorities from initial consultation

Points to consider:

- Current research capacity
- How do we measure benefit
- Market readiness
- Ability to build on existing research.
- How to capitalise on work (especially European experiences)

Leveraging completed research / innovation – focus on extension

Knowledge management is a cross cutting issue and will be considered for all investment plan reviews. Communication of past research is a big problem. Presentation could be short pieces of text/short video/ which target social media/ LinkedIn. FWPA can be portal to broader research. Individual companies will also continue to hold IP. Where should mutually beneficial information reside? Strong need to collate and share. Hubs may be able to play a part in sharing and making information available. Need to ensure that information remains available beyond the life of the organisation. Look to examples where research has been transferred successfully to operations.

How do we document how research outcomes resulted to a change in operations (impact). What is the problem were trying to address, how will this be achieved and what is the impact? Beware of research that fails to understand operationally feasibility. The path to commercialisation has a number of metrics that change from building knowledge through to commercialisation. Impact changes at each phase.

Consider asking growers what their top 3 problems are they which to solve. i.e., koala detection and unauthorised access. Come up with some problem statements to frame the plan and support the list of prioritised research needs.

Opportunities for FWPA to have a portal. Each company has an obligation to manage technological problems. Many ways to transfer knowledge. FWPA growers can get information from project steering committees and in-kind participation often do a webinar which is recorded and posted and /or present at Forestry Australia and Forest Tech.

FWPA would be the logical gate keeper/repository/archive stored/retrievable. Periodic literature reviews on specific topics i.e. mechanical planting options. FWPA could facilitate series of workshops/ information sessions on specific areas of interest. Webinars are part of the project proposals. There is still a lot information residing within companies that would be suitable for sharing i.e. Wolfgang Drexler FWPA could share information about Resitool. Strong support shown for the idea of capturing 5 top problems.

Options for measuring potential gains / benchmarking current performance against – Group discussion

Conclusions / Actions

This workshop has brought together a lot of expertise. FWPA has a concept of creating interest groups that could get together quarterly/annually and have a structured conversation - maybe a useful platform at some stage – looking for the will and commitment. Gottstein trust fund is available to create overseas exchanges. Need to keep abreast of developments through AFWI to prevent duplication of effort. There is a lot of demand on organisations to stay involved and informed. Very important to have practitioners driving the research.

Appendix 2 – List of relevant and recent research projects

List no.	Group	Category	Title
1	FWPA 2020 Investment Plan	General	Improved utilisation of existing systems and technology through data analysis and extension SCO 1.1.1
2	FWPA 2020 Investment Plan	General	Improved data acquisition, retention, and management for supply chain ROI SCO 2.1.1
3	FWPA 2020 Investment Plan	General	Increasing the total resource ROI through extended product identification, capture and deliver SCO 3.1.1
4	FWPA 2020 Investment Plan	General	Improved supply chain management frameworks and systems with increased integrations towards more efficient, safer and profitable operations - Supply chain efficiency, safety and compliance SCO 4.1.1
5	FWPA 2020 Investment Plan	General	Improved supply chain management frameworks and systems with increased integrations towards more efficient, safer and profitable operations - ROI driven supply chains SCO 4.1.2
6	FWPA 2020 Investment Plan	General	Improved supply chain management frameworks and systems with increased integrations towards more efficient, safer and profitable operations - Harvester head technology SCO 4.1.3
7	FWPA 2020 Investment Plan	General	Improved supply chain management frameworks and systems with increased integrations towards more efficient, safer and profitable operations - Management of within supply chain inventories SCO 4.1.4
9	FWPA / USC Agreement	General	State of system and technology deployment in Australian forest industry
10	FWPA / USC Agreement	Harvesting	Technology integrated with harvester data to support improved value realisation
		In supply chain inventory	Subproject: Sensor technology for improved value recovery
11	FWPA / USC Agreement	In supply chain inventory	Testing automated measurement of in-supply chain inventory and key supply chain infrastructure performance
		In supply chain inventory	Mauricio Acuna - Accuracy and precision of DBH measurements obtained with Apple's iPad Pro 2020 and 3D modelling software in Eucalyptus nitens stands
		In supply chain inventory	Subproject: Impacts of stand location and log position within Pinus radiata trees on return-to-log values based on log dimensions and wood density and the implications to the log supply chain
		In supply chain inventory	Subproject: Individual Log ID Tagging and Tracking

List no.	Group	Category	Title
		In supply chain inventory	Subproject: Individual Log ID Tagging and Tracking literature review
	IEA Bioenergy	Forest residues / biomass	USC is the Operating Agent for IEA Bioenergy Task 43, with Professor Mark Brown the Task Leader. The Task explores technical and economic strategies to increase the quantity of biomass available, improve the quality of biomass delivered for different energy purposes, and explore strategies to increase the value and foster confidence in biomass supply for both direct and cascade use of biomass for energy
12	IEA Bioenergy	Forest residues / biomass	1. Reducing moisture content and biomass quality for energy through biohub screening
13	IEA Bioenergy	Forest residues / biomass	2. Site productivity impacts of intensified biomass recovery – literature and knowledge review
14	IEA Bioenergy	Forest residues / biomass	3. Better understanding of biomass characteristics for energy / Multipurpose biomass and commodities characterization for innovative biohubs
			The following other activities have also been approved to proceed
15	IEA Bioenergy	Forest residues / biomass	- Comprehensive Literature, Case Study and Best Practice review for Biomass Supply Chains and Biohubs
16	IEA Bioenergy	Forest residues / biomass	- Integration of Agricultural and Municipal Solid Waste in Bio-Hubs in Canada
17	IEA Bioenergy	Forest residues / biomass	- Biohubs business models
18	IEA Bioenergy	Forest residues / biomass	- Life cycle analysis of storage strategy when using forest residues for heat and power
19	IEA Bioenergy	Forest residues / biomass	- Integrated assessment of the impact of biomass hubs/terminals in improving the efficiency and resilience of bioenergy supply chains using bi-level simulation modelling and scenario analysis
20	IEA Bioenergy	Forest residues / biomass	- Feedlog stock supply for bioenergy in T43 member countries
21	IEA Bioenergy	Forest residues / biomass	- Assessment of value and quality impacts of salvage (post fire or insect impact) harvested biomass
22	NIFPI	Harvesting	Future proofing SA blue gum plantations through improved detections of koalas in early planning in forestry operations

List no.	Group	Category	Title
23	NIFPI	Harvesting	Wearable sensors for improving OHS - pilot prototype for harvesting and processing operations
24	NIFPI	Harvesting	Development of best practice guidelines for protective guarding of mobile plant in Australian forests
25	NIFPI	Carbon	Development of the timber industry sector framework for setting carbon emissions targets
26	NIFPI	General - Health and Safety	Development of best practice fatigue management for the Australian forest industry
27	NIFPI	Harvesting	Optimising machinery configurations for profitable harvesting operations of small-scale plantations
28	NIFPI	Harvesting	Short logs supply chain impacts in hardwood plantations
29	NIFPI	Harvesting	Assessing the economic impact of damage to eucalyptus nitens logs during mechanised harvesting operations
30	NIFPI	In supply chain inventory	Managing moisture content in the supply chain, construction and in-service
31	AFORA	Forest residues / biomass	Harvesting low-productivity eucalypt plantations for biomass. CRC for Forestry Bulletin 19, July 2011
32	AFORA	Transport	Reducing forestry transport costs with FastTRUCK. CRC for Forestry Bulletin 30, September 2012
33	AFORA	Forest residues / biomass	Bundling harvest residue in shining gum plantations. CRC for Forestry Bulletin 15, February 2011
34	AFORA	Harvesting	Bunching stems in steep slopes for efficient yarder extraction. CRC for Forestry Bulletin 17, May 2011
35	AFORA	Harvesting	Machine productivity of roadside chipping in a thinned pine plantation. CRC for Forestry Bulletin 24, May 2012
36	AFORA	Harvesting	Evaluation of the Hitman PH330 acoustic assessment system for harvesters. CRC for Forestry Bulletin 25, May 2012
37	AFORA	Harvesting	Bunching stems in steep slopes for efficient yarder extraction. CRC for Forestry Bulletin 17, May 2011
38	AFORA	Harvesting	Quantifying the value recovery improvement using a harvester optimiser. CRC for Forestry Bulletin 26, May 2012
39	AFORA	Forest residues / biomass	'FibrePlus' study: Harvesting stemwood waste pieces in pine clearfall. CRC for Forestry Bulletin 18, July 2011
40	AFORA	Harvesting	Maintaining harvester measurement accuracy to maximise value recovery. CRC for Forestry Bulletin 28, June 2012
41	AFORA	Processing	Assessment of harvest residues from different harvesting operation sites in Australia. CRC for Forestry Bulletin 31, September 2012
42	AFORA	Harvesting	Choosing the right feller-buncher head for maximum volume extraction. CRC for Forestry Bulletin 22, March 2012

List no.	Group	Category	Title
43	AFORA	Harvesting	Maintaining harvester measurement accuracy to maximise value recovery. CRC for Forestry Bulletin 28, June 2012
44	AFORA	Forest residues / biomass	'FibrePlus' study: Harvesting stemwood waste pieces in pine clearfall. CRC for Forestry Bulletin 18, July 2011
45	AFORA	Forest residues / biomass	Forwarding technologies to collect harvesting residues for bioenergy use. CRC for Forestry Bulletin 32, October 2012
46	AFORA	Harvesting	Volume recovery comparison for four different harvesting methods in short-rotation blue gum plantations. CRC for Forestry Bulletin 27, June 2012
47	AFORA	Forest residues / biomass	Productivity of the Bruks chipper when harvesting forest biomass in pine plantations. CRC for Forestry Bulletin 16, April 2011
48	AFORA	Harvesting	Application of MultiDAT onboard computers for management of native forest harvest operations. CRC for Forestry Bulletin 20, August 2011
49	AFORA	Harvesting	Comparing the efficiency of four harvesting methods in a blue gum plantation in south-west Western Australia. CRC for Forestry Bulletin 29, June 2012
50	AFORA	Harvesting	Review of new ground-based logging technologies for steep terrain. CRC for Forestry Bulletin 21, January 2012
51	AFORA	Harvesting	Benchmarking feller-buncher productivity in Western Australian blue gum plantations. CRC for Forestry, Harvesting and Operations Bulletin 12, October 2010
52	AFORA	Harvesting	Best practice harvester calibration. CRC for Forestry, Harvesting and Operations Bulletin 2, October 2008
53	AFORA	Processing	Evaluation of an in-field chipping operation in Western Australia. CRC for Forestry, Harvesting and Operations Bulletin 4, April 2009
54	AFORA	Harvesting	Comparing harvester productivity in third-row versus fifth-row thinning of a Eucalyptus nitens plantation. CRC for Forestry, Harvesting and Operations Bulletin 6, December 2009
55	AFORA	Harvesting	Preliminary results: volume recovery comparison of different harvesting systems in short-rotation hardwood plantations. CRC for Forestry, Harvesting and Operations Bulletin 9, April 2010
56	AFORA	Harvesting	Benchmarking feller-buncher productivity in Western Australian blue gum plantations. CRC for Forestry, Harvesting and Operations Bulletin 12, October 2010
57	AFORA	Forest residues / biomass	European biomass harvesting systems and their application in Australia. CRC for Forestry, Harvesting and Operations Bulletin 10, September 2010
58	AFORA	Harvesting	Effects of different log stocking densities on harvesting of blue gum stands in Western Australia. CRC for Forestry, Harvesting and Operations Bulletin 5, June 2009
59	AFORA	Transport	Forest truck fuel consumption survey. CRC for Forestry, Harvesting and Operations Bulletin 8, April 2010

List no.	Group	Category	Title
60	AFORA	Forest residues / biomass	Review of commercial wood-fuelled electricity and heat generation technologies. CRC for Forestry, Harvesting and Operations Bulletin 7, April 2010
61	AFORA	Transport	The impact of tare weight on transportation efficiency in Australian forest operations. CRC for Forestry, Harvesting and Operations Bulletin 3, December 2008
62	AFORA	Transport	Analysis of factors that affect the transport efficiency of in-field chipping operations. CRC for Forestry, Harvesting and Operations Bulletin 11, September 2010
63	Uni of Melbourne	Forest residues / biomass	Strandgard, M.; Taskhiri, M.S.; Acuna, M.; Turner, P. Impact of Roadside Drying on Delivered Costs for Eucalyptus globulus Logging Residue and Whole Trees Supplying a Hypothetical Energy Plant in Western Australia Using a Linear-Programming Model
64	Canterbury Uni NZ	General	Forest Engineering school includes work on operational efficiency - no details available
	SCION	General	https://www.scionresearch.com/science/growing-the-value-of-forests/boosting-forest-productivity
65	CSIRO	Forest residues / biomass	Rotation Optimisation Tool
66	UTAS (ARC for Forest Value)	Forest residues / biomass	Woo, H (2020) Forestry biomass residue supply chains in Tasmania: developing a digital tool and enhancing modelling to improve data accuracy, location mapping and impact assessments for future bioenergy. University of Tasmania
67	UTAS (ARC for Forest Value)	Logistics	Neagoe, M (2021) Investigating landside congestion at bulk cargo terminals in Forestry supply chains: A role for information systems. University of Tasmania. Publication pending
68	UTAS (ARC for Forest Value)	Logistics	Krisanski, S (2021) Evaluating methods for the capture and analysis of digital and physical samples in complex forest environments. University of Tasmania. Publication pending.
69	UTAS (ARC for Forest Value)	Forest residues / biomass	Woo, H, Acuna, M, Moroni, M, Taskhiri, MS, Turner, P (2018) Optimizing the Location of Biomass Energy Facilities by Integrating Multi-Criteria Analysis (MCA) and Geographical Information Systems (GIS). Forests 9, 585. DOI: https://doi.org/10.3390/f9100585
70	UTAS (ARC for Forest Value)	Forest residues / biomass	Woo, H, Moroni, M, Park, J, Turner, P (2020) Residues and Bio-energy Generation: A Case Study Modelling Value Chain Optimization in Tasmania. Energy 196, 117007. DOI: https://doi.org/10.1016/j.energy.2020.117007
71	UTAS (ARC for Forest Value)	Forest residues / biomass	Woo, H, Turner, P (2019) A review of recent research on carbon neutrality in forest bioenergy feedlog stocks. Research Journal of Environmental Sciences 19, 556014. DOI: https://doi.org/10.19080/IJESNR.2019.19.556014

List no.	Group	Category	Title
72	UTAS (ARC for Forest Value)	Forest residues / biomass	Strandgard, M, Turner, P, Mirowski, L, Acuna, M (2019) Potential application of overseas forest biomass supply chain experience to reduce costs in emerging Australian forest biomass supply chains – A literature review. Australian Forestry 82, 9-17. DOI: https://doi.org/10.1080/00049158.2018.1555907
73	Oregon State Universit - College of Forestry	Forest residues / biomass	http://www.forestry.oregonstate.edu/research/biochar
		Harvesting	Lyons, K., J. Sessions and J. Wimer. 2020. The effect on tether tension when using trees to redirect live machine tethers during forest harvesting on steep slopes. Biosystems Engineering 195(2020):89-96
		Harvesting	Garland, J., F. Belart, R. Crawford, W. Chung, T. Cushing, S. Fitzgerald, P. Green, L. Kincl, B. Leshchinsky, B. Morrissette, J. Sessions and J. Wimer. 2019. Safety in steep slope logging operations, Journal of Agromedicine 24(2):138-145.
		Harvesting	Sessions, J., B. Leshchinsky, W. Chung, K. Boston, and J. Wimer. 2017. Theoretical Stability and Traction of Steep Slope Tethered Feller-Bunchers. Forest Science 63(2):192-200
		Harvesting	Green, P., W. Chung, B. Leshchinsky, F. Belart, J. Sessions, S. Fitzgerald, J. Wimer, T. Cushing, and J. Garland. 2019. Insight into the Productivity, Cost and Soil Impacts of Cable-assisted Harvester-forwarder Thinning in Western Oregon. Forest Science 66(1): 82-96

Appendix 3 – Full list of research topics tabled via industry consultation July / August 2023

Broad Topic	Ref	Theme	Research need / notes
Knowledge Management	A1	Knowledge repository	Accessing previous research outcomes - need advice on world's best practice / best options re. technology and systems available
	A2	Knowledge repository	Storing research data and outcomes
	A3	Extension services	Deploying research successfully - focus on technology transfer
	A4	Extension services	Retention of collective industry knowledge - stop revisiting issues / solutions from 70's – 90's
Harvesting	B1	Automation and robotics	Autonomous /remotely controlled machines Connectivity here is suboptimal
	B2	Chipping efficiency	In-field chipping - improved transport and chipping efficiency through detached staging bins - congestion in Portland chip terminal - comparison of different logistical arrangements - distance from port - research exists as does operational experience with success
	B3	Harvesting productivity	Productivity impacts of multiple products being cut in hardwood plantations - measurement of impact on harvesting costs - impact on the haulage task, but many variables due to landing restrictions - site specific - review previous work conducted
	B4	Harvesting productivity	Harvester mounted technology to improve tree selection in thinning (stand density as well as tree quality) https://youtu.be/aO-9d31F8VI
	B5	Harvesting productivity	Mapping of thinned trees / tracks to enable precise subsequent rotation planting for establishment of outrows
	B6	Harvesting productivity	Thinning up/down slope - improving track location and pattern - potentially results in removing too much of the crop at thinning. Plan where extraction tracks should be.
	B7	Harvesting productivity	Value of tree-marking at thinning - costs and benefits - company-specific question (variation between companies) - advance tech to improve operator selection

Broad Topic	Ref	Theme	Research need / notes
	B8	Industry skills	Operator training - offsite to enable better productivity for new operators - benchmarking productivity - simulators used for training internationally - offsite training facility without production pressure - consistency of work/contracts - simulator training in Tasmania - where does simulator training work well? - existing research ~10 years old, simulators have improved
	B9	Koala detection	Koala spotting and protection- focus on cost reduction (Cross check NIFPI project)
	B10	Machinery fuels	Electrification / alternative fuels - harvesting equipment
	B11	Machinery fuels	Cost and operational impacts of higher standards for non-road diesel engines (Tier 4 and 5) - understanding fire risk (work has been done for trucks)
	B12	Steep harvesting	Steep harvesting - winch assist implementation, operator training - anchor point for Hoop pine - specific to HQP
	B13	Log stock management	Improved inventory management between stump and delivery - bridging gap between harvest head data and roadside log stock calls -carrying high log log stocks -inefficient truck movements
	B14	Value recovery	Hardwood Plantations - Value recovery / matching demand / product utilisation - being able to be as effective as established softwood ops
	B15	Value recovery	Centralised log processing to maximise value - understanding costs, benefits and risks - reliant on customer locations
	B16	Value recovery	Sorting in-forest (for length, diameter, MoE) v logyard - potential to share value if market dynamics are addressed/solved, currently impacted by supply/demand imbalance
	B17	Wet weather logging	Wet weather logging, focus on durability of road networks, cost effective means of replacing infrastructure (eg. Bridges) - difficulty getting bridge logs and more damage from extreme events - engineered timber solutions, timber durability, glued joints (potential for ARC Linkage project) - competition with plastic pipes, steel spans - important to have regulator/waterway managers input - hydrology and engineering specs
Residues	C1	Residue economics	Understanding costs and improving extraction efficiency (across different terrain types) - extraction to marketing - variable knowledge across sector - biomass value is increasing, some Aust specific work is possible

Broad Topic	Ref	Theme	Research need / notes
	C2	Residue economics	Residue storage and processing options
	C3	Residue economics	Decision support tool required to assess benefits and costs (eg. to site productivity), nutrition supplementation
	C4	Residue markets	Understanding material availability / attributes
	C5	Residue markets	End-use focus (we already know enough about extraction and costs), how is it converted and where?
Transport	D1	Automation and robotics	Truck platooning - autonomous trucks - productivity, safety
	D2	Transport efficiency	Self-loading trucks - costs, options, benefits - Australian restrictions - what are the barriers? (weight) - Canadians have phased this out - Expensive unless different loading sites frequently (fewer loader movements)
	D3	Transport efficiency	Transport efficiency - centralised despatch - where, what, costs and benefits - better suited to AFPA - potential study to test out configurations - damage to infrastructure etc.
		Transport efficiency	Meeting PBS requirements - getting better industry collaboration / leverage with state and local government - zero tolerance, underloading - can be costed. - public infrastructure risk
		Transport efficiency	Weighing systems - improved technology and operational implications - impacted by landing quality
	D4	Transport fuels	Electrification / alternative fuels - trucks, impediments for electrification / hydrogen - Fennell trials ongoing - opportunity for mills to generate renewable energy for recharging
		Transport safety	Load restraint / covering loads - costs and options. Safety issues of throwing chains etc. - research has been done
	D5	Transport safety	Improved capture and use of data use to meet HVNL requirements (mass+speed+fatigue)
	D6	Transport safety	Safety - transport, driver monitoring / assist technology / eg. car technology - lane assist, other alert systems - much is in new trucks now
Plantation Operations	E1	Automation and robotics	Mechanical planting - options, costs, Making use of existing equipment to reduce capital costs - nursery specs will need to match planting method/machine - HQP - particular issues with Hoop pine

Broad Topic	Ref	Theme	Research need / notes
General	F1	Reporting	Overall emissions - need better baseline and focus on both measuring efficiency and particulates - factors required to be used are internationally mandated/nominated
	F2	Contract management	Benchmarking / contract indexation mechanism - standardised industry tool (eg. mining industry have universal mechanism to index rates) - not research
	F3	Social licence	Improving the environmental credentials of timber harvesting operations