Forest & Wood Products Australia

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Research, development and extension investment plan

Research, development and extension priorities for native forest silviculture.

2020

Adapted from *FWPA RDE Investment Plan – Native Forest Silviculture*, prepared for FWPA by Author: John Hickey

This version of the Investment Plan, adapted by FWPA in December 2020, removes the cost and benefit estimates from the original Investment Plan, FWPA RDE Investment Plan – Native Forest Silviculture, prepared for FWPA by Author: John Hickey.

Author declaration of interest

The author retired from full-time work in 2014. He now does occasional forest consultancies and is currently a member of the Board of the Tasmanian Forest Practices Authority. He received no income in the past year from RD&E carried out by the author in the technical areas addressed in this investment plan. The author anticipates receiving no income in the next five years from RD&E activities carried out by the author in the technical areas addressed by this investment plan.

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Executive Summary

This investment plan addresses 16 areas of RD&E for native forests silviculture, spread across four themes, for the Australian native forest sector from 2019/20 to 2023/24, with an outlook to 2028/29 and beyond to 2040. This sector is overwhelmingly important for Australia's supply of hardwood sawlogs and also supplies speciality timbers that are used for a range of special and decorative purposes. The sector is largely influenced by five public native forest growers that supply 60% of Australia's native forest sawlog harvest. The calculated sustainable yield for high quality sawlogs from public native forests from 2020-40 is 1.1 million m^3/y (MPIGA and NFISC 2018). There is no calculated sustainable yield for private native forests.

Research done in the 1990s under the Young Eucalypt Program developed thinning as a silvicultural treatment for even-aged regrowth. High costs and a decline in pulpwood export markets from 2010 to 2015 reduced thinning programs to limited areas with easier terrain. However, the recent improvement in markets for small logs as export pulpwood and peeler logs is causing regrowth thinning programs to expand.

Over the last decade there has been a silvicultural research focus on: managing habitats; alternatives to clearfelling in south-eastern Australia; low productivity outcomes from high retention silviculture in north-eastern Australia; and, mitigating effects of bushfires and climate change. More focus is needed on research to improve productivity, increase efficiencies and reduce avoidable costs for native forest growers. The research areas with most potential to help achieve this include:

- Remote sensing to better target suitable areas for commercial thinning and reduce on-ground planning and supervision costs.
- Remote sensing to reduce compliance costs, such as for measuring regeneration success.
- Matching seed provenances and species to future site conditions to mitigate the effects of climate change.
- Developing silviculture for integrated harvesting of areas previously subject to sawlog-only operations (due to low markets for residues) to restore productivity.

Recent international silvicultural research in natural and semi-natural forests indicates 15 practices that are not widely deployed currently in Australian native forests. The most relevant of these are:

1. Bioenergy harvesting (productivity and sustainability aspects)
2. Commercial thinning
3. Digital aerial photography (DAP) analysis for mapping and monitoring
4. Retention silviculture (variable retention)
5. Variable-density thinning for habitat maintenance and restoration.

The research agenda of the Canadian Forest Service, FVA (Forest Research Institute) Baden-Wuerttemberg Germany, Skogforsk Sweden and the PNW Research Station of the US Forest Service was reviewed. There are opportunities and benefits to be gained by fostering collaborative research with these, and similar, agencies.

Achievable gains for growers in the native forest sector are listed under four themes: *productivity, sustainability credentials, social acceptance* and *industry capacity.*

Research priorities to increase *productivity* over the next five years include: adopting remote sensing to identify areas for thinning and automating regeneration surveys; improved silviculture (integrated harvesting) for high-graded native forest; avoiding growth losses due to climate change by matching provenances and species to future site conditions; decision support tools to assist developing harvest plans; and, better understanding of the needs and aspirations of private native forest growers. In addition to gains in these areas, cost-efficient thinning of an additional 1000 ha/y of highly productive ash-type forest could deliver a ten percent increase in the sustainable sawlog yield from public native forests from 2070. Research on matching seed provenances to future site conditions could deliver additional savings from 2080 onwards.

Research priorities to increase *sustainability credentials* over the next five years include: guidelines for responsible recovery of timber from burnt forests; prescriptions for retention of coarse woody debris (CWD) habitat when high residue removal harvests are planned; and, a national workshop on long-term monitoring to identify cost-effective approaches that meet management, regulatory and certification requirements.

Research priorities to increase *social acceptance* over the next five years include: exploring options for reduced reliance on clearfelling and high-intensity burning by better understanding how the public makes judgements on silviculture at a landscape level; and determining the relative importance of burnt versus unburnt seedbeds for eucalypt productivity beyond the regeneration phase.

Research priorities to increase *industry capacity* in silviculture include: supporting a Native Forest Silviculture Interest Group for growers and research providers to share ideas and knowledge and to advise on the implementation of the recommended FWPA program of silviculture RDE; an annual award for the best undergraduate thesis in native forest silviculture to encourage a supply of future silviculturists; a standardised classification of silviculture terminology; and development of training materials for native forest growers, employees and contractors.

Appendix 5 of this plan provides justifications for each recommended project and outlines some of the anticipated benefits for each project. Appendix 5 also lists potential proponents for detailed project development.

Gains from investments in increasing sustainability credentials, social acceptance and increased industry capacity are difficult to quantify although their importance is very large. For example, a loss of social licence for public native forestry would stop the sustainable yield of sawlogs from public native forest and considerable annual stumpage payments, plus the value-added through downstream processing. Similarly, a lack of investment in future silviculturist and training may well debilitate the public and private native forest sector.

Three barriers to achieving gains in delivering this plan are potential deficiencies in:

Development of detailed project briefs and support by growers. The successful implementation of this research plan will require a high level of engagement between native forest growers and research providers. The first challenge will be for the potential proponents to commit to developing detailed project briefs, with appropriate contributions of cash and in-kind support. In-kind support will be crucial in focussing the research on field forestry matters and exposing the researchers to the operational issues that influence the relevance of the intended research solution.

Expertise in native forestry among service providers. Public native forest growers have outsourced their research functions to other state agencies and universities which has delivered some efficiencies in delivering focussed research but has diminished the strong knowledge and extension capability provided by in-house researchers of previous times. It is likely that there is still (just) enough expertise in native forest research to deliver the projects listed in this investment plan.

Expertise and capacity among forest growers to deploy research developments. This is more likely to be a significant risk for deployment by private forest growers than public growers and will need to be a particular focus for private native forest grower support agencies such as the Queensland Department of Agriculture and Fisheries, Private Forest Services Queensland, Local Land Services NSW and Private Forests Tasmania.

Projects costs and qualitative benefits are summarised below.

Project	**Anticipated Benefits**
1. Commercial thinning guided by remote sensing	Short: savings in planning and compliance costs; savings in harvest costs. Long: increased sustainable sawlog yield.
2. Remote sensing regeneration success	Short: savings in survey and compliance costs; reduced risk to field staff.
3. Integrated harvesting of high-graded forests	Short: increased yield of treated forest. Long: sustainable sawlog yield from private forests.
4. Options for improving jarrah productivity	Long: increased yield of jarrah sawlogs.

Project	Anticipated Benefits
5. Evaluation of previous productivity investments	Short: informed thinning programs.
6. Understanding needs of private native forest growers	Short: targeted assistance programs. Long: sustainable sawlog yield from private forests.
7. Climate-adapted protocols for provenances and species	Short: climate-adapted seed provenance protocols. Long: avoided yield losses.
8. Decision-support apps for harvest planning	Short: savings in harvest plan preparation.
9. Guidelines for responsible recovery of timber from burnt forests	Short: increased value from sale of fire-damaged timber. Long: maintain rights to harvest fire-damaged forests.
10. Coarse Woody Debris prescriptions for high residue removals	Short: increased access to responsible bio-energy markets.
11. National workshop on long-term monitoring	Short: cost-effective monitoring approaches to meet regulatory and certification requirements.
12. Reduced reliance on clearfelling and high-intensity burning	Short: increased understanding of public preferences for alternatives; clarification of the importance of burning for long-term eucalypt forest productivity.
13. Community engagement approaches for native forest growers	Short: handbook for operational community engagement for Australian native forest growers.
14. Future silviculturists: NFS Interest Group and undergraduate support	Short: knowledge transfer from research providers and growers; develop next cohort of silviculturists.
15. Standardised silvicultural classification and terminology	Short: reduced misunderstanding within the forestry profession and the general public.
16. Training materials (procedural manuals/videos/apps) for native forest growers, employees and contractors)	Short: prioritised list of required training materials; at least one new training material for each State by 2023.

The suggested weighting of the RD&E budget apportioned across the four themes is:

Increasing productivity	59%
Increasing sustainability credentials	18%
Increasing social acceptance	8%
Increasing industry capacity	15%

Research priorities to increase *productivity* beyond 2023/24 include a focus on: growing value, rather than volume; application of large UAVs for aerial sowing (and burning); silvicultural prescriptions to underpin mechanical fuel reduction to avoid bushfires; LiDAR for inventory and growth estimation; growth simulators for guiding silvicultural manipulations; and, digital aerial photography for mapping tree species, habitat features and forest health surveillance. Research priorities to increase *sustainability credentials* include automated monitoring systems for biodiversity; understanding nutrient balances for sustainable biomass harvesting; and, variable-density thinning for habitat enhancement. The priority to increase *social acceptance* is to investigate alternative slash treatments, and market opportunities to sell higher volumes of residues, to reduce reliance on clearfelling and high intensity burning in wet eucalypt forests. Research investments to increase *industry capacity* include an authoritative (online) silvicultural text for Australia's native forests and a continuing focus on developing future silviculturists by promoting interest and opportunities among existing, and potential, employees.

Beyond 2028/29 it is anticipated that native forests will be increasingly regarded as a source of niche products, including high quality sawlogs and timbers for special purposes. Because the proportion of high value sawlogs is usually less than one-quarter of the bole volume of a stand, a focus on high value sawlogs will also require a focus on markets for arisings, in order to maintain forest productivity and health as well as economic production. If markets for low quality wood can be developed, particularly for bioenergy, there will be more interest from private native forest growers to manage parts of their property for ongoing timber production. Hence research priorities beyond 2029 should include strategies to identify a stable private native forest estate so that a sustainable yield can be calculated to complement the supply from public forests and inform investment decisions in processing. Other major priorities should include research on stand management to identify optimum densities for climate change resilience and to mitigate against a likely increase in bushfires, pests and diseases.

1. Introduction

a. Objectives

This investment plan addresses 16 areas of RD&E for native forests silviculture, spread across four themes, for the Australian native forest sector from 2019/20 to 2023/24, with an outlook to 2028/29 and beyond to 2040. The plan was commissioned by Forests and Wood Products Australia (FWPA) Limited in accordance with its 2017-2022 strategic plan, which identified five programs designed to grow the market for forest and wood products, increase productivity (and implied profitability) across the value chain, and ensure positive environmental and social outcomes.

The FWPA Strategic Plan notes that *for the native forestry sector to be successful it must be able to overcome its capability constraints. The sector will need to embrace more fully a culture of diversity and innovation, including knowledge generation and adoption, technical transfer, skill development, continuous improvement and international best practice and do these things in a consistent, continuous and sustained manner. Native forestry is a long-term venture that is exposed to environmental risks (e.g. pests, fire, climate change), occupational health and safety risks as well as market and political risk. Improved knowledge and systems can help mitigate these risks and expand the economic and sustainable outcomes for the industry, including the provision of new environmental services. By raising awareness of best practice and new technologies, industry can build the capability to evolve commercial operations and reap the benefits of innovation*.

FWPA's strategic plan identified a number of strengths, weaknesses, opportunities and threats including four which are particularly relevant to this NFS plan and include:

- *Improve national coordination of current and new forest grower research activities.*
- *Develop decision support tools to assist the farm and private native forest sector to manage commercial tree crops as a sustainable investment strategy.*
- *Provide professional development programs to ensure that current and future decision makers are using information that is evidence-based and compatible with international best practice.*
- *Ensure that forest management and forest operation tools deliver in-field practices that are scientifically sound, safe and compatible with international best practice.*

Native forest silviculture can be defined as the art and science of producing and tending a native (natural or semi-natural) forest for the various social and economic values demanded by individuals and society. Native forest silviculture has a utilitarian history of over 100 years in Australia that, particularly on private land, has sometimes led to high-grading and left forests in poor condition. This Investment Plan seeks to encourage and support committed forest growers who manage native forests for sustainable high value timber production in accordance with forest regulations and certification

standards. The proportion of high value sawlogs is usually less than one-quarter of the bole volume of a stand. Paradoxically a focus on high value sawlogs also requires a focus on markets for other bole volume, also known as residues or arisings, in order to maintain forest productivity and health as well as economic production. A similar situation occurs for grain producers who need markets for associated biomass production and beef farmers who need markets for lower value meat even though their focus is on prime meat production.

b. Background

The native forest sector continues to be significant, as part of Australia's overall forest sector, both in area and product terms. In 2015-16 Australia had 28.1 million hectares of native forests available and suitable for commercial wood production (MPIGA and NFISC 2018) of which 6.3 million hectares (20%) was on public land. When additional local restrictions to maintain and manage non wood values are taken into account the net harvestable area of Australia's public native forests was 5.0 million hectares. The annual area of public native forest from which wood was harvested for the period from 2011/12 to 2015/16 was 78 000 hectares, of which 9% was by clearfelling, 0.2% was by variable retention, 5% was by shelterwood and 86% was by selective harvest systems.

From 2011/12 to 2015–16, the annual volume of logs harvested from native forests was 4.1 million m^3, which represents 16% of Australia's total log supply. Around 2.1 million m^3 of sawlogs were harvested annually from native forest (mostly hardwood species) over this period compared to 0.2 million m^3 of sawlogs from Australia's hardwood plantation estate. While softwood plantations continue to supply about 80% of Australia's sawlogs, the native forest sector remains overwhelmingly important for the supply of hardwood sawlogs. Native forests are also a source of speciality timbers that are important for a range of special and decorative purposes.

There has been a progressive reduction in native forest harvest volumes over the last 20 years due to reductions in areas available for wood production, and changes in national and international markets. The market demand for many native forest products has improved over the last five years, assisted by a reduction in the foreign exchange rate against the US dollar. The sustainable yield of high-quality sawlogs from publicly managed native forests is forecast at 1.1 million m^3/y for the period from 2020-40. After that time, it is forecast to increase slightly, given no further reductions in net harvestable area, and successful management of risk from wildfire, disease and climate change (MPIGA and NFISC 2018).

The native forest sector is largely influenced by wood supplies from five state government agencies, hereafter referred to as public native forest growers, listed in Table 1 (South Australia does not have native forest areas designated for wood production).

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Table 1. Public native forest growers, production in 2017/18 (from agency annual reports)

State	Public forest Grower	Forest custodian	Production			Profitable	Certification
			sawlog (all grades)	other bole volume	Total		
			m^3 million	m^3 million	m^3 million		
NSW	Forest Corporation of New South Wales (Hardwood Division)	FC NSW	0.32	0.56	0.88	yes	AS 4708
QLD	Forest Products: Department of Agriculture, Fisheries and Forestry	DAF	0.26	0.00	0.26	NA	AS 4708
TAS	Sustainable Timber Tasmania	STT	0.17	0.99	1.16	yes	AS 4708
VIC	Vicforests	DELWP	0.48	0.82	1.30	yes	AS 4708
WA	Forests Products Commission	DBCA	0.13	0.36	0.49	yes	AS 4708, FSC-CW
TOTAL			**1.36**	**2.73**	**4.09**		

DELWP = Department of Environment, Land, Water and Planning (Victoria)

DBCA = Department of Biodiversity, Conservation and Attractions (WA)

Table 1 suggests, when compared with Australia's log supply statistics from 2015/16, that the five public native forest growers supply over 60% of Australia's native forest sawlog harvest and close to 100% of Australia's supply of other bole volume from native forest. Furthermore, this supply is profitable and certified as sustainable. Knowledge and innovation in silviculture is more likely to occur, and be consistently deployed, among public native forest growers than among the private native forest growers. However, the public native forest growers are lean organisations, and R and D is largely outsourced to research providers, mainly within universities or state agencies.

Private native forests are still a significant source of native forest sawlogs although there are no current estimates of the net harvestable area of private native in Australia (MPIGA and NFISC 2018). Similarly, there is insufficient information nationally to assess whether the current or future rate of wood harvest from private native forests is sustainable. However, increasing regulatory restrictions on harvesting operations on private land in all states have led to a reduction in wood harvest volumes from private

forests. The current annual supply of sawlogs of about 0.3 million m3/y from private native forests is mainly sourced from Queensland, New South Wales and Tasmania (MPIGA and NFISC 2018).

Methodology

The project to prepare the Plan was informed by the following elements:

1. An *inception meeting* held by teleconference on 17/1/19 with the steering committee assigned by the FWPA Grower Advisory Committee. The participants at the meeting, and at two subsequent workshops are listed in Appendix 1, which summarises the stake holder engagement undertaken for this Investment Plan. The purpose of the meeting was to:

- Confirm the scope of the work
- Identify key stakeholders (forest growers and research providers) to contribute priorities.
- Identify dates for workshop consultations.
- Confirm project timeline and deliverables.

2. A preliminary list of 18 potential native forest silviculture research, development and extension projects, prepared by the consultant, was sent to primary contacts at each of the five public native forest growers. Contacts were asked to rate the projects as either Higher (H) or Lower (L) from their perspective and to identify any additional priorities for their jurisdiction. This resulted in a list of 23 projects which were used as a start point for a brainstorming session with forest grower representatives.

3. *Workshop 1 Brainstorming with grower representatives*. This was held 22/2/19 as a 2-hour teleconference (with the consultant and Melbourne-based people attending at the FWPA's office) and aimed to assist key growers identify a preliminary set of research priorities, and collaborative opportunities, to address their native forest management needs. The participants were presented with a summary of information from previous FWPA projects on native forests from the last decade (back to 2009) and a tabular summary of the 23 potential native forests that arose from responses from public native forest growers under step 1 above. The workshop identified a top ten list of priorities, and potential collaborative themes, for broader discussions with private forest grower representatives and potential research providers.

4. Discussions with research providers and private native forest representatives. Growers research priorities were discussed with native forest researchers at the University of Melbourne and University of Tasmania (see Appendix 1 for stakeholder consultations). Research needs for other states were informed by discussion with Martin Rayner (Western Australia, DBCA), Tom Lewis (Queensland) and Doland Nicholls (New South Wales). Research needs for private growers were informed by discussions with representatives from Private Forest Services Queensland and Private Forest Tasmania.

5. *Listing of relevant previous and current FWPA- and other-sponsored RDE activities relating to silvicultural management*

The consultant prepared a list of FWPA research projects relevant to native forest silviculture sponsored by the FWPA for the past decade (2009). The consultant also considered major native forest silvicultural research projects prior from 1990 to 2009, including those sponsored by Australian and State Governments under Regional Forest Agreements. Further information on activities and outcomes from native forest silviculture was gleaned from an analysis of papers published in *Australian Forestry* over the last decade. This journal was chosen because it is most likely to be used, and read, by Australian silviculturists. It is recognised that many worthwhile papers on native forest silviculture have been published elsewhere, particularly in *Forest Ecology and Management*, as well as in local journals such as *Tasforests* and in "grey literature" produced by forest management agencies. Some of these papers were also considered, but a full consideration of all literature was beyond the scope of this review.

6. Relevant international RDE not yet deployed widely in Australia

The consultant used the following methods to identify relevant RDE not yet deployed widely in Australia's native forests:

- Review of recent annual reports of selected research organisations in Canada, Germany, Sweden and the United States of America. The review was biased towards countries with well-developed economies, extensive commercial native and semi-natural forests and to organisations with people that have collaborated with Australian silviculturists or that the author met through overseas forestry tours in 2001 (IUFRO thinning conference in Canada), 2007 (study of variable retention silviculture in the Pacific North-West) and 2011 (Gottstein Fellowship to Germany and Sweden).
- Listing a selection of recent peer-reviewed journal articles published by staff at these organisations on aspects of native forest silviculture.
- An evaluation of a international practices with potential relevance to Australia based on descriptions in Ashton and Kelty (2018) *The Practice of Silviculture—Applied Forest Ecology.*

The four organisations selected for this review are listed below:

Country	Research Organisation	Employees (approx.)
Canada	Canadian Forest Service (includes six regional research stations)	200 research staff, (800 total)
Germany	FVA (Forest Research Institute) Baden-Wuerttemberg	300
Sweden	Skogforsk Swedish Forest Research Institute	120
United States	PNW Research Station, US Forest Service	300

7. *Workshop 2 with grower representatives and selected research providers.* This was held on 13/3/19 as a 4-hour teleconference (with the consultant and Melbourne-based people attending at the FWPA's office) to consider relevant international RDE not yet deployed widely in Australia and to discuss the draft list of national research priorities, collaborative opportunities and potential research proponents for particular projects. Participants are listed in Appendix 1.

8. *Quantification of productivity and value gain made internationally in comparable or relevant forests and climates through silvicultural management*

Workshop 2 discussed relevant international silvicultural RDE derived from step 6 to consider its potential to make productivity gains, or avoid losses, if deployed in Australia.

9. Quantification of the potential productivity gains to Australia's forest estate based on deployment of current R&D, international practices and potential future practices

A suite of research category investments was developed through literature searches, interviews with native forest growers and research providers and confirmed at Workshop 2. Likely productivity, value gain or avoided losses for deployment of these silvicultural practices in Australia was informed by expert opinion, particularly at workshop 2. These discussions identified a set of highly prospective projects for the period from 2019/20-23/24. Indicative costs were determined based largely on the likely length and nature of the research. A lower level of precision was undertaken for projects recommended to commence after June 2024.

10. Industry and research provider capabilities, including the need to access and availability of international RDE expertise

The author considered research capability and interest through interviews with prospective research providers and from feedback at the stakeholder workshops. He also listed research providers who had contributed research papers to *Australian Forestry* over the last decade (Appendix 6). Where the required capacity does not exist in Australia, the author identified potential international providers.

3. Analysis of current state of NFS Silviculture RDE, operational practice and gains

a. In Australia

FWPA has funded and published reports on eight projects with relevance to native forest management and silviculture RDE over the last decade. Appendix 2 summarises the findings of these projects and Table 2 summarises their subjects and deployment implications.

Table 2. Summary of deployment for native forest silviculture investments by FWPA since 2009.

Subject	Key implication for management	Deployment/policy outcomes
Carbon stocks and flows in native forests	No reason to halt native forestry for carbon sequestration. Increased use of biomass for energy would improve carbon budgets.	Bioenergy from native forests recognised by policy makers as greenhouse positive.
Scoping study for native forest investment plan	Native forest growers not ready in 2014 to identify collaborative themes for relevant research, due to economic and socio-political issues.	Investment Plan deferred for 5 years.
Contribution of CAR reserves to production landscapes	Networks of reserves within a large production matrix is effective at maintaining biodiversity.	Metrics based on proximity to reserves used for gauging reserve needs, and for sustainability reporting.
Variable retention silviculture insights from Pacific NorthWest America	Using variable retention rather than clearfelling generally achieved social and ecological objectives.	About 7000 ha of native forest was harvested by clearfelling annually from 2011/12 to 2015/16, with about 200 ha/y harvested by variable retention (MPIGA and NFISC, 2018).
Review of the science of public native forest management in Victoria	Excellent compendium of knowledge.	Low awareness of report among scientists, forest managers and the broader public.
Growth predictions in private spotted gum forests in Qld and NSW	Silvicultural guidelines for extension officers and landowners. Decision support tool to estimate growth on specific sites. Demonstration trials.	Limited uptake due to lack of residue markets. Used by Private Forest Services Queensland to assist landowners manage about 10 000 ha of private native forest for sustainable production

Subject	Key implication for management	Deployment/policy outcomes
Review of impacts of plantations and native forests on water security.	Indicated that impacts of plantations on water security were overemphasized. Native forests exert the overwhelming control on water availability at a large catchment scale.	Informed the debate about plantations and water security at a time of rapid plantation expansion.
Variable retention harvest system	Early findings from a long-term experiment of the efficacy of variable retention in Victorian mountain ash forest.	Variable retention could be suitable for flatter parts of the landscape (about 30% of coupes). Intention to monitoring biodiversity responses until 2030 (or at least 2020).

Table 2 indicates that the eight investments in aspects of native forest management and silviculture have been worthwhile and informed complex debates on carbon, landscape ecology, alternatives to clearfelling, low productivity in private native forests, and water use. Only one of the projects was aimed at increasing productivity (silvicultural guidelines for private spotted gum forests), which had limited application due to a lack of residue markets. The review of the science of public native forest management in Victoria was very thorough but appears to have had little readership, perhaps due to a long delay between completion of the review in 2005 and its eventual publication in 2011.

Other native forest silviculture RDE investments

The consultant also considered major native forest silvicultural research projects prior to 2009, including those sponsored by Australian and State governments under Regional Forest Agreements. Major projects in native forest silviculture RDE, including monitoring, since 1990 are summarised in Table 3.

Table 3. Major projects in native forest silviculture RDE from 1990 to 2008.

Project/Partners	Established	Description
The Young Eucalypt Program (YEP). CSIRO, Forestry Commission Tasmania, Victorian Department of Conservation and Environment, Forest Industries Association of Tasmania, and the Victorian Sawmillers Association	1988 (5 years)	The YEP aimed to: • Estimate the area of eucalypt regrowth available and suitable for thinning; • Predict growth response from thinning; • Evaluate spacing and thinning technologies; • Reduce damage to retained trees caused by thinning operations; • Develop methods for debarking; • Develop methods for drying sawn timber from young, small trees; • Assess suitability for Kraft pulping; and, • Conduct economic analyses of alternative management regimes.
Victorian Silvicultural Systems Project. Department of Conservation and Environment, Victoria.	1990 (5+ years)	The Silvicultural Systems Project (SSP) in mountain ash forest at Tanjil Bren examined a suite of silvicultural options involving a wide range of gap sizes (small to large) and overwood densities (nil to complete). Results from SSP have helped refine the clearfell and seed-tree methods to obtain improved environmental outcomes (for example, understorey islands). Selection and shelterwood systems have been shown to have limited applicability because of Occupational Health and Safety issues, poor growth rates of the regeneration, and damage to retained trees. The Silvicultural Systems Project in low elevation mixed species (LEMS) forest trialed a range of silvicultural treatments at the Cabbage Tree Creek study area. It showed that early growth is detrimentally affected by high levels of overstorey retention and confirmed that the seed-tree silvicultural system is the most cost-effective system for many of the east Gippsland LEMS forests.
Warra Long-Term Ecological Research Site. Forestry Tasmania plus eight site partners	1995 (20+years)	A 15,900 ha long-term ecological research site in Tasmania's major tall wet eucalypt forest type, with local, national and international partners.
IFM Program. Tas RFA, (Forestry Tasmania)	1997-2004 (plus monitoring)	Operational and research funding to maintain sawlog supply from reduced RFA land base by operational pre-commercial and commercial thinning operations in native forest (and by establishing plantations on pruned and thinned regimes).
Warra Silvicultural Systems Trial, Forestry Tasmania	1997-2004 (plus monitoring)	Trial of clearfelling and alternatives in tall wet *E.obliqua* forest, with emphasis on safety, silvicultural, biodiversity and social acceptability outcomes. The trial is designed to compare clearfell, burn and sow with five alternative treatments that include the following: 1. Clearfell, burn and sow with understorey islands. 2. 80 m width stripfells. 3. 10-15% (basal area) dispersed retention. 4. 30% (canopy

Project/Partners	Established	Description
		area) aggregated retention. 5. Single tree/small group selection (openings < one mature tree height wide) and 6. Group selection (openings < two mature three heights). The trial area was burnt by the major Riveaux Road wildfire in January 2019.
FORESTCHECK Department of Environment and Conservation, Western Australia	2001 (+ ongoing monitoring)	FORESTCHECK is an integrated monitoring project, established in 2001 to inform forest managers about changes and trends in key elements of forest biodiversity associated with a variety of management activities. FORESTCHECK monitoring is designed to provide information relevant to a number of regional level indicators of ecological sustainable forest management, and it samples a wide range of organisms at multiple sites across the main environmental gradients in the jarrah forest. Monitoring has focused initially on the effects of timber harvesting and associated silvicultural treatment including regeneration release through gap creation, regeneration establishment using shelterwood, and selective harvesting. Forty-eight monitoring grids, each 2 ha in size, have been established within four of the jarrah forest ecosystems mapped for the Western Australian Regional Forest Agreement. FORESTCHECK is included in the Australian network of long-term monitoring sites,
Standardised measure of regeneration success for native forests, Victorian Centre for Forest Tree Technology	1999-2001	This project, funded under the national Wood and Paper Industry Strategy, aimed at standardising measures for reporting against Montreal Protocol Indicator 2.1 (regeneration success). It involved statistical evaluation of current procedures across NSW, Tasmania, Victoria and Western Australia and recommendations for improvement. The project is regarded as a good example of multi-state national research and has been used to indicate the statistical basis for reporting regeneration success under forest certification schemes.
Variable retention for tall oldgrowth forests, Tasmanian Community Forest Agreement, Forestry Tasmania	2005-2010	Operational and research funding to develop and implement variable retention for coupes containing at least 25% oldgrowth in Tasmania's wet eucalypt forest.
Variable Retention Harvesting System Trial, Department of Sustainability and Environment, VicForests and the Australian National University	2002-2006 (+ ongoing monitoring)	Comparison of two different configurations of small patches (0.5 and 1.5 ha in size) of retained forest within otherwise clearfelled, burnt and sown coupes in mountain ash regrowth forests in Victoria. Wherever possible, the patches included old habitat trees.

Native forest silviculture RDE reported in Australian Forestry

Australian Forestry has published 62 papers with relevance to native forest silviculture RD&E over the last decade (Appendix 3). This represents about one quarter of the total papers published in that journal. The focus of these papers across Australia was national (13%), NSW (11%), Qld (8%), Tas (18%), Vic (26%) and WA (26%). The topics addressed by the papers are summarised in Table 4.

Table 4. Topics addressed by papers relevant to native forest silviculture published in *Australian Forestry* from 2009-2018.

Habitat management	23%
Silvicultural systems	15%
Bushfire mitigation	10%
Climate change effects	8%
Carbon accounting	6%
Forest products	6%
Forest health	6%
Thinning	5%
Remote sensing	3%
Forest policy	3%
Seed management	3%
Soil impacts	3%
Water impacts	3%
Training	2%
Yield modelling	2%
Landscape management	2%

Table 4 indicates that habitat management, silvicultural systems (alternatives to clearfelling in south-eastern Australia, and low productivity outcomes from high retention silviculture in north-eastern Australia), bushfire mitigation and climate change effects have been well discussed, although much remains to be done. Conversely, topics such as thinning, remote sensing, seed management, soil and water impacts have received little attention over the last decade.

Table 5 categorises the same papers into four over-arching themes: Productivity, Avoiding Losses, Maintaining Capacity and Social Acceptance.

Table 5. Themes addressed by papers relevant to native forest silviculture published in *Australian Forestry* from 2009-2018.

Avoiding Losses	66%
Maintaining Capacity	2%
Productivity	26%
Social Acceptance	6%

Table 5 indicates the bulk of the research was directed towards avoiding losses, particular of habitat but also from climate change effects. Almost no research was directed towards maintaining capacity of native forest management. While a quarter of the research was directed to productivity, most of this was concerned with reduced productivity (e.g. by retained overwood and alternatives to clearfelling) rather than increasing it (e.g. by thinning). Research on social acceptance considerations might be considered low, especially since maintaining a social licence is a key issue for native forestry.

The conclusions that can be drawn from this analysis of the current state of NFS Silviculture RDE, operational practice and gains is that much of the recent research has been directed largely to avoiding losses and very little has been directed to increasing productivity or maintaining capacity. Much useful research was done under the Young Eucalypt Program, and Tasmania's Intensive Forest Management (IFM) program to develop thinning as a silvicultural treatment for even-aged regrowth. Continued implementation of regrowth thinning programs in Tasmania and Victoria has been challenged by the decline in pulpwood export markets from 2010 to 2015 which caused programs to be reduced to limited areas with easier terrain. However, the recent improvement in markets for small logs as either export pulpwood or peeler logs is causing regrowth thinning programs to expand. Two decades ago, there was a strong emphasis on the establishment of long-term silvicultural systems trials and on long-term monitoring of effects on biodiversity. This level of commitment has been difficult to maintain in recent times due to changes in forest managing agencies and roles, as well as retirements of the first generation of proponents.

Over the last decade there has been a research focus on managing biodiversity, alternatives to clearfelling in south-eastern Australia, low productivity outcomes from high retention silviculture in north-eastern Australia and mitigating effects of bushfires and climate change. Thinning, remote sensing, seed crop development, soil and water impacts have received little attention.

While habitat management and soil and water considerations must remain important considerations for native forest growers, and as required by forest regulation and certification which have become well developed since the advent of Regional Forest Agreements, it seems that more research focus should now be focused on research to improve productivity, increase efficiencies and reduce avoidable costs for native forest growers. The research areas with most potential to help achieve this include:

- Remote sensing to better target suitable areas for commercial thinning and reduce on-ground planning and supervision costs.
- Remote sensing to reduce compliance costs such as for regeneration surveys.
- Matching seed provenances and species to future site conditions to mitigate the effects of climate change.

- Silviculture for integrated harvesting of areas previously subject to sawlog-only operations (due to low markets for residues) to restore productivity.

3b. Analysis of current state of RDE internationally

Australia's native forests are dominated by eucalypts and are different from other forest types around the world. They are characterised by:

- A high fire frequency, especially in dry forests. Less frequent, but sometimes stand-replacing, fires occur in wet forests.
- Adaptations to fire (e.g. seed protected in woody capsules, thick bark, epicormic buds, lignotubers).
- Shade-intolerance which correlates with rapid colonisation and growth after disturbance as well as strong self-thinning.
- Crowns that allow relatively high levels of sunlight to reach the forest floor. This allows the development of dense understoreys, especially in wetter environments.

From a commercial perspective, eucalypt timber is traditionally viewed as a useful hardwood for many structural and appearance grade purposes but not ranked in the top echelon of global valuable timbers. Sawlog grade material is often much less than 25% of gross bole volume which means that harvesting generates large volumes of lower grade material which is difficult to market against hardwood fibre from eucalypt plantations. Large amounts of slash are also generated by harvesting, which impedes regeneration unless removed by prescribed burns. The domestic processing industry for lower grade material is under-developed in much of Australia, so distant overseas markets need to be sourced. This is in marked contrast with the situation in countries such as Germany where a diverse range of markets for lower grade material, including for bioenergy, are readily accessible.

These biological and commercial factors mean that some silvicultural practices and RDE employed in native (natural) and semi-natural forests internationally are not suitable for application in Australia. Others may be suitable but have not yet been deployed in Australia. The results from the review of recent research programs by selected research agencies in Canada, Germany, Sweden and the United States are reported below.

Canadian Forest Service

The Canadian Forest Service (CFS) is part of the department of Natural Resources Canada. The CFS is a science-based policy organization responsible for promoting the sustainable development of Canada's forests and competitiveness its forest sector. The CFS has its head office in Ottawa and 6 research centres across the country.

The CFS maintains a searchable website of its publications. Information on silviculture is readily accessible and includes Plain English abstracts of scientific articles. Researchers at the CFS have published over 60 journal articles relating to silviculture over the last decade (since 2009). These cover a diverse range of topics including

- Creating stands that are more resilient to climate change by underplanting different species
- Effects of silvicultural systems on biodiversity
- Late age fertilisation to stimulate growth
- LIDAR Inventory to plan commercial thinning
- Long-term effects of pre-commercial thinning (PCT)
- Managing for value, rather than volume, in hardwoods
- Managing heterogenous stands with irregular shelterwoods.

Recent studies include:

- Antos et al (2016) who developed silvicultural methods, including partial-cut systems and extended rotations for high value species (in this case Western Red Cedar). Studies of this kind might be relevant for developing silvicultural methods for Australian species such as white cypress pine.
- Filipescu et al (2017) which indicates that late rotation nitrogen fertilisation of Douglas-fir forests may lead to a significant growth response with only minimal reduction of fibre properties.
- Gebramichael et al (2005) which indicates that commercial thinning of 40-year-old Douglas fir is profitable over a 55-year rotation length as long as thinning revenues exceed treatment costs.
- Lamb et al (2018) who forecast inventory variables from LiDAR imagery to guide commercial thinning of planted spruce forests.
- Lussier et al (2014) who describe a method for treating stands with low productivity due to past diameter-limit cutting. This may have some relevance for managing native forests in Queensland that may have been high-graded by diameter limit cutting.
- Pitt et al (2013) who report the rotation-length effects of pre-commercial thinning (PCT) and weed suppression on Net Present Value of balsam fir forests treated at 8 years and harvested at about 50 years. At a discount rate of 4% PCT offered NPVs of $550/ha and could lead to a doubling in value of treated stands.

FVA (Forest Research Institute) Baden-Wuerttemberg

The FVA (Forest Research Institute) in Baden-Wuerttemberg is the research facility of the Baden-Wuerttemberg (BW) government in south-west Germany and has close links with Albert-Ludwigs-University. The university carries out predominantly fundamental research while the FVA conducts

practical research and development for the BW Forest Service and private forest owners. Many projects are carried out in close cooperation with the other Forest Research Institutes in Germany or neighbouring countries. It has eight departments which include Forest Growth, Forest Nature and Conservation, Soil and Environment, Forest Health, Forests and Society, Forests Utilisation, Forest Economics and Biometry and Computer Science. In 2017, FVA hosted the 125th IUFRO Conference (International Union of Forest Research Organisations), which included over 2000 scientists from more than 100 countries.

For the last two decades public forests in Baden-Weurttemberg have been managed according to close-to-nature forestry principles, which are now used widely in Central Europe and involve no clearfelling (except for salvage) and a transition away from monoculture plantations of Scots pine and Norway spruce, which were used for reforestation after the original forests were plundered during the Industrial Revolution. While these plantations served to help alleviate wood shortages and protect drinking water storages, they had decreased biodiversity, encouraged invasive species, reduced forest resistance to wind and ice storms and increased problems with insects and disease (Ashton and Kelty 2018). In recent decades European societies have demanded a management approach that diversifies tree species composition, increases biodiversity, and is more ecologically similar to the original forests prior to land clearing.

The 2017 FVA Annual Report (latest available) describes the following recent projects in detail:

Tree species of the future. Given that all the main current tree species are showing effects of climate change, an extensive literature-based collection of profiles for 25 tree species was put together in the search for alternatives. The species profiles contain information about distribution and ecology, the link with habitat, stocking, performance, wood characteristics and wood usage, other ecosystem functions, biotic and abiotic risks and silvicultural aspects.

The W+ growth simulator. This is a tool for decision making when treating forest stands. Currently, it has been parametrized for spruce, Douglas fir and beech monocultures, based on data from FVA treatment trials of thinning from below, growing stock maintenance and various final cutting strategies, so that a broad spectrum of silvicultural measures can be planned. This simulator estimates diameter and basal area growth by using a combination of single tree and forest stand models. An important guideline for developing the simulator was that it could also be used by forest practitioners and therefore the input data needed to be easily attainable in practice. Just a few parameters, such as the basal area or the number of trees and average stand diameter, as well as age and top height, suffice to use the program.

Mapping from Digital Aerial Photography (DAP). The aim of this project is to develop practical methods of estimating forest stand parameters from digital aerial photographs. Stereo photography allows extracting digital surface models (DSMs) by using image matching methods. The spectral information of

the photographs can be used to classify forest types and tree species. The photographs are regularly acquired by the state government in a three-year cycle. Sample plots from forest inventories were used as a reference to model forest variables such as timber volume (m^3/ha) and forest types. A standard process was used to extract point clouds from the aerial stereo photographs and to generate raster-DSMs (digital surface models) with spatial resolution of 1 m. Normalized digital surface models (nDSM) were calculated by subtracting a laser scanning based digital terrain model (DTM) from the photogrammetric DSM. The height of the nDSMs is equivalent to the forest height. The height values of the raster can be aggregated into classes to obtain height structure maps with 5 m x 5 m grid. It can be used to create a variety of digital map products, including

- Homogeneity maps to estimate crown closure.
- Forest types maps based on an automatic classification of forest types (coniferous and broad-leaf) using spectral information of aerial stereo photographs.
- Timber volume maps that are a 20 m x 20 m raster product derived from a model-based approach that combines information derived from the sample plots and explanatory variables extracted from digital elevation models. The timber volume maps are in an evaluation phase and are not yet a final product.

Remote sensing data from analysis of digital aerial photography provides new information that can be used for operational planning, forest biotope mapping, health surveillance, conservation planning and wildlife management. Furthermore, digital mapping of small-scale forest structures over a time series will allow monitoring of canopy change.

Soil restoration techniques. Since the 1960s, there has been a steady increase in the weight of forestry machinery that can destroy soil structure, especially when operated under sub-optimal conditions. In this study, three skid trails were created on which the following treatments were applied:

- the addition of lime to improve the formation of aggregates and to reduce soil acidification, promoting biological activity.
- a mechanical treatment during which the topsoil is mixed with plant residues (mulch).

The skid trails were then planted with six tree species selected based on cultivation experience and tree physiological characteristics (e.g., adaptation to anaerobic conditions). The survival rates and biometric parameters of the planted trees show significant differences between treatments. The survival rates of all tree species were higher on the treated skid trails compared to the untreated skid trails and the non-compacted control plots.

Economics of habitat protection required of private forest growers under EU protocols. The Natura 2000 network is the EU contribution to Areas of Special Conservation Interest for the conservation of European wildlife and natural habitats. Natura 2000 sites are selected according to criteria for each

biogeographical region. Forest growers fulfilling Natura 2000 conservation objectives are experiencing additional management expenditures and reduced income. This study projected timber production in Natura 2000 forests to be reduced by 0.4 m^3/ha/y to an average of 6.1 m^3/ha/y, equivalent to about -50€/ha/y. The economic consequences of implementing Natura 2000 are moderate for the overall forest sector in Baden-Wuerttemberg but for some Natura 2000 sites, the reduction of timber production values may reach a magnitude where individual forest growers are seriously affected. In state forests additional expenditures and reduced income are borne by the state forest enterprise. Whether or not municipalities obliged to implement Natura 2000 will be reimbursed by the state is not yet resolved. Private forest owners implementing Natura 2000 by choice are already being offered a financial compensation lump sum of 50 € per hectare per year. However, the participatory approach depends heavily on the good will of the stakeholders.

Recent studies of potential relevance to Australian silviculturists and native forest growers include:

- Albrecht et al 2012, which investigated the influence of soil, site, forest stand, and tree parameters on storm damage and found that tree species and stand height are the most important storm risk factors.
- Benneter et al (2018) collected data on crown size, stem form and tree health for over 12 000 trees within naturally diverse forests to assess the impact of tree species richness on these characteristics. They found that diverse stands are not inferior regarding stem quality, while at the same time being able to provide various other ecosystem services**.**
- Madrigal-Gonzalez et al (2016) compiled growth data of the 14 most dominant tree species in 32 628 permanent plots covering boreal, temperate and Mediterranean forest biomes to investigate the effect of species mixing on stand productivity.
- Nil et al (2011) reported levels of bark damage caused by partial harvesting, based on inventory data across Baden-Wuerttemberg.
- Wilpert et al are working on a current project for identification of the wood biomass potential which can be mobilized in German forests in a sustainable way, based on the nutrient availability in forest soils.

Skogforsk (Swedish Forest Research Institute)

Sweden's commercial forests are best described as semi-natural forests. Forest management in Sweden can be characterized by even-aged silviculture heavily relying on three established harvest regimes: clearcutting, the seed-tree method, and the shelterwood system. Regeneration is often by planting, augmented by natural seed. Fire is not a major consideration in Swedish forestry.

Skogforsk is the central research body for the Swedish forestry sector and is financed jointly by the government and the members (mainly forest growers). The demand-driven applied research includes forest technology, raw-material utilization, environmental impact and conservation, forest tree breeding, logistics, forest bioenergy and silviculture. The Institute's staff of about 120, includes 20 staff in its silvicultural program. Skogforsk has close links with the Swedish University of Agricultural Sciences, which conducts fundamental forest research.

Skogforsk operates under its *Research and Innovation Strategy 2017-2020*, which seeks to:

- Develop genetically improved plant material adapted to the future climate and to meet the needs for forest raw material.
- Develop silviculture for different objectives.
- Develop efficient operational systems with minimal environmental impact.
- Develop all opportunities afforded by digitalisation.
- Develop value chains and raw material use that enable the bioeconomy.
- Develop and clarify societal benefits of forestry.

Note that much of the research conducted by Skogforsk is by contracts with individual forest growers and therefore is reported privately, rather than through published journals. Recent studies of potential relevance to Australian silviculturists and native forest growers include:

- Drossler et al (2017) studied natural regeneration in a planted Scots pine-spruce forest. The creation of canopy gaps had a positive effect on total seedling density five years after harvest, mainly due to a significantly higher number of *Betula pendula* individuals.
- Fahlvik et al (2018) studied 41 pre-commercial thinning experiments in Scots pine forest in Sweden thinned at various ages and densities. The land expectation value generally decreased with increasing mean height at PCT, primarily because of the increased cost of PCT.
- Futter et al (2016) developed a framework to evaluate, summarize and communicate the most important issues where land management and other anthropogenic pressures combine to impair water quality.
- Gustaffson et al (2012) outlined retention forestry's ecological role, reviewed its current practices, and summarized the large research base on the subject from a global perspective. Retention forestry is applicable to all forest biomes, complements conservation in reserves, and represents bottom-up conservation through forest manager involvement.
- Lundmark et al (2016) compared carbon balances between continuous cover and clear-cut forestry in Sweden and found only minor differences in long-term climate benefit.

- Rosenberg et al (2010) studied the implications of returning wood-ash to forest ecosystems in order to replenish nutrients removed when small branches have been extracted as a source of bioenergy. The results suggest that wood-ash application can deplete soil organic C at spruce sites with an N-rich soil.

PNW Research Station, US Forest Service R&D

The research and development (R&D) arm of the Forest Service, a component of the U.S. Department of Agriculture, consists of seven research stations and 81 experimental forests and ranges. The Pacific Northwest (PNW) Research Station is a leader in the scientific study of natural resources. The Station has 11 laboratories and research centres in Alaska, Oregon, and Washington as well as 12 active experimental forests, ranges, and watersheds. It is a key partner with Oregon State University in the science program at the Andrews Experimental Forest established in 1948, which is an LTER (Long-Term Ecological Research) Site.

The PNW is focussed on the following research topics: Climate Change, Ecology, Ecosystems and Environment, Environment and People, Fire, Forests and Plant Health, Forest Products, Inventory Monitoring and Analysis, Resource Management and Use, and Wildlife.

Staff from the PNW Research Station authored 24 journal articles relating to silviculture in the decade since 2009. Recent studies of potential relevance to Australian silviculturists and native forest growers include:

- Baker et al (2013) reviewed global knowledge of mechanisms and scales at which forest influence operate and showed that these are highly variable. Important general factors and mechanisms that underlie the ability of organisms to re-establish include qualities of retained elements, dispersal capacity, suitability of habitat conditions, and interspecific interactions, all of which may vary with distance from intact mature forest.
- Chmura et al (2011) considered likely ecophysiological responses of forests to climate change. Elevated C02 and warmer temperatures may have positive effects on growth and productivity where there is adequate moisture or growth is currently limited by cold. However, the effects of climate change are generally expected to reduce growth and survival, predispose forests to disturbance by wildfire, insects, and disease; and ultimately change forest structure and composition at the landscape scale.

- Ruzicka et al (2017) measured tree growth and intrinsic water-use efficiency (iWUE) based on stable carbon isotopes to investigate impacts of density reduction across a range of progressively finer spatial scales: site, stand, hillslope position and neighbourhood.
- Urgenson et al (2013) studied patterns of conifer regeneration over 12 years as part of a regional-scale experiment in variable-retention harvest in the Pacific Northwest. Growth was distinctly reduced in dispersed treatments and (or) at higher levels of retention. Density of natural regeneration was 1.5-2.5 times greater in dispersed treatments than in the cleared areas of aggregated treatments.
- Wills et al (2018) examined the effects of variable-density thinning (VDT) 14 years after treatment in five young mixed-conifer stands to investigate whether thinning had accelerated the recruitment of large trees (> 80 cm dbh), recruitment of shade-tolerant species into the mid-story (40–65 cm), or development of longer crowns relative to the unthinned sub-treatment.
- Youngblood et al (2011) describes the network of experimental forests established by the US Forest Service, including the Pringle Falls Experimental Forest established in Oregon in 1914.

This review of recent international silvicultural research in natural and semi-natural forests indicates 15 practices that are not widely deployed currently in Australian native forests. These are summarised in Table 6. Some of these practices have been implemented in Australia in special circumstances, such as when funds have been provided under Regional Forest Agreements in order to increase productivity of the remaining public native commercial forest estate as a compensation for transferring production forests into conservation reserves. Forms of retention silviculture are widely practiced in many Australian commercial native forests (but not often named as such) but are less common in wet eucalypt forests of south-eastern Australia where clearfelling is commonly applied. For these forests, retention is often applied at the adjoining landscape rather than within the coupe.

The research agenda of the four forest research institutes examined for this review is much broader than the agenda for the FWPA Investment Plan, which is focussed on research to increase productivity, or avoid losses, for native forest growers. Another key difference is that the four institutes have access to much larger, and longer term, data sets to underpin their research. For example, Germany has a comprehensive national forest inventory system based on plots across public and private native forests. The US Forest Service has experimental forests that have been yielding data for more than a century. While these resources are generally well beyond those available to Australian research silviculturists there are opportunities and benefits to be gained by fostering collaboration between Australian and overseas forest research agencies. Good examples already exist (see papers by Baker et al (2013) and Gustaffson et al (2012)). It is also noteworthy that recent PhD studies by Australian silviculturists (eg.

Mark Neyland, Robyn Scott) have involved co-supervision by expert staff from international forest research institutes. Such opportunities should be encouraged wherever possible.

Table 6. Summary of relevant international RDE with some potential for application in Australia's commercial native forest.

Practice/reference	International Application	Application in Australia	Relevance to FWPA Investment Plan
Bioenergy harvesting, productivity and sustainability	Widely practiced in Europe.	• Increasing interest but only happening at small-scale. • Markets for residues are key to improving productivity of high-graded native forest (particularly on private land). • How much small wood can be harvested without depleting soil nutrients and losing productivity? • Appropriate silvicultural prescriptions need development (to provide for retention of nutrients and coarse woody debris habitat)	High
Commercial thinning	Common in Sweden and Canada. Timing and distribution of thinning can be assisted by LiDAR analysis. Commercial thinning increases NPV.	• Thinning improves productivity by focussing growth on the best trees and harvesting wood that might otherwise be lost to mortality. • Commercial thinning is practiced in NSW, Victoria, Tasmania and WA but limited by high planning and supervision costs • Associated fire risks can be managed. • Containing costs of harvesting and monitoring, through better information on ground and stand conditions, will improve profitability.	High
Compensation measures for private native forest growers for habitat conservation.	Keen issue in Germany where EU habitat protocols are mandated	• Limited scope for compensation to private growers.	Low

Practice/reference	International Application	Application in Australia	Relevance to FWPA Investment Plan
Digital aerial photography (DAP) analysis for mapping and monitoring	Emerging	• LIDAR derived terrain models plus DAP-derived canopy imagery can be very powerful. DAP provides point cloud data for canopy mapping as well as colour information. • Applications might include regeneration surveys, canopy species mapping and forest health surveillance.	High
Establishing forests without prescribed slash burns	Common practice in Europe and now Canada	• Noticeable reduction in public acceptance of smoke from slash burns. The burning window is getting narrower and more difficult with climate change and reduced appetite for risk. • Practical alternatives tied to residue markets and bio-energy markets. • Burning has ecological benefits as well as drawbacks. • Reduced intensity burning is a more realistic goal than no burning in the Australian context. • Initial work might focus on drawing together what we know about eucalypt and understorey plant responses to high intensity vs low intensity vs no burn options. Also need to consider cost comparisons. • Later work could involve trials of high residue harvesting and mechanical treatment options (including slash-busting machinery). • Research on reduced reliance on high-intensity burning is important to help maintain a social licence.	Medium
Establishing mixed tree species forests for climate resilience	Now a common practice in Central Europe.	• It is both a commercial and an environmental issue. What risks do we have? What tools can we develop to adapt to changing site conditions?	High

Practice/reference	International Application	Application in Australia	Relevance to FWPA Investment Plan
		• This could be applied through sowing or planting of multiple species, eg. pure *E. regnans* stands could include a component of *E. obliqua* to increase resilience to fire and climate change. • This is most relevant to managing provenance selection in the Australian context.	
Growth simulators for growers (such as FPS, ORGANON, and W+)	Developed in Europe and North America to model complex stand management interventions and predict future timber, habitat and other outcomes.	• Growers needs are currently met by simple timber yield models, but future demands might require forecasting a broader range of outputs. • The technology to capture data inputs for simulators is getting cheaper (LiDAR, DAP and UAVs). • Germany and the US have standardised multi-tenure national forest inventory systems (which Australia lacks), which provide data to parameterise growth simulators.	Medium
Long-term ecological and silvicultural trials	Common in Pacific NorthWest and Europe. Experience in North America is that long-term trials have unforeseen benefits as new questions arise.	• ForestCheck continues to be successful and supported. • Vic SSP sites largely abandoned but treatments continue to be relevant (eg overstorey retention for arboreal mammals). • Warra Silvicultural Trial impacted by 2019 wildfire, which could allow new insights on recovery. • Most long-term trials/data-sets established by former forest management agencies cannot be supported by current lean State native forest growers (maybe some role for FWPA?).	High

Practice/reference	International Application	Application in Australia	Relevance to FWPA Investment Plan
		• Initial priority is to review information from current long-term trials, identify what questions might be answered by further monitoring and are there alternative (cheaper) ways of getting the information.	
Managing stand density to increase resilience to climate change (or water production)	Active research in Europe and North America on thinning to promote resilience to drought.	• WA has thinning trials established in 1975 that demonstrate long term benefits for water production and climate resilience. Not done operationally due to lack of markets for thinnings. Bioenergy markets are being sought. • Victorian research indicates that regrowth stand densities will drop under future climate scenarios, through drought-induced mortality, so that future stands could carry about 20% less volume than they do now. Victoria (DEWLP) is potentially interested in alternative harvesting strategies that would deliver ecosystem services. • NSW parks does some ecological thinning of River Red Gum forests to increase water production and increase biodiversity.	Medium
Mid-rotation fertilisation (aerial applications)	Sometimes used in planted Douglas fir forests (with positive NPVs).	• Growth responses in native forests are uncertain but some information could be gleaned from fertilised plots established by CSIRO (Mike Connell) in *E. sieberi* (NSW) and by Ann LaSala in *E. obliqua* (Tas). A recent PhD thesis by Soraya (ANU Supervisor Cris Brack) includes analysis of the CSIRO plots. • Maybe appropriate as a solution to a regulated sustainable yield issue, but unlikely to be economic or desirable under normal circumstances.	Low

Practice/reference	International Application	Application in Australia	Relevance to FWPA Investment Plan
		• Fertiliser can be an option for rehabilitation of damaged native forest areas.	
Optimising set-asides for biodiversity management in commercial forest	Keen issue in Sweden where policy caps mandatory set-asides to 5%.	• Set-asides need active management to provide their desired objectives. • Could involve developing silviculture for habitat enhancement. • Possible need to develop monitoring protocols for set-asides and test if objectives are being met (certification and RFA drivers).	Medium
Pre-commercial thinning: development of mechanical methods	Common in Sweden but manual methods are too costly. Mechanical methods are being developed.	• Operational scale program by stem-injection in young regrowth in Tasmania as part of compensation funding (with limited evaluation of outcomes). • Future application limited by lack of funds. • Analysis and write-up of well-designed trials from the 1990s (CSIRO-Mike Connell, Forestry Tasmania-Ann LaSala) would inform pre-commercial thinning responses.	Low But legacy trials in Tasmania and NSW could be remeasured and reported.
Restoration of snig tracks through fertiliser applications, mulching or planting of tolerant tree species	Research phase?	• Vicforests do some restoration of snig tracks and landings, based on past trials. FPC and STT do some ripping and grooming. • All growers believe current techniques are adequate.	Low

Practice/reference	International Application	Application in Australia	Relevance to FWPA Investment Plan
Retention silviculture/ Variable Retention	Increasingly used as an alternative to clear cutting in the Pacific North West. Also used in Sweden but retention levels are low.	• One of the key social licence issues for native forestry is clearfelling and high-intensity burning in tall wet eucalypt forests. • Most Australian forest growers incorporate significant landscape retention at the landscape, rather than the stand scale, eg STT has a Landscape Context Planning system which requires at least 20% of the public native forest within 1km of a coupe centroid to be retained for the long term (100+ years). • STT uses aggregated retention for stands with particular social or biodiversity significance in Tasmania. • VicForests continue to support biodiversity evaluation of long-term Variable Retention Harvest System trials in Victoria. • ANU (Cris Brack) is seeking to introduce VR terminology to NSW private foresters. • Growers find variable retention difficult to implement. ENGOs may prefer an end to native forestry rather than softer silviculture. General public usually not aware of alternatives (or indifferent). • UniMelb study (Ford et al) developed simulations to test public attitudes at stand level. Landscape level studies (Smith et al) not widely reported. A key paper could be written by Rebecca Ford from the study if supported by modest FWPA funding. • VicForests are interested in VR as part of its certification strategy.	Medium (high for VicForests)
Variable-density thinning	Practiced in multiple use forests managed by	• Relates to "Managing stand density to increase resilience to climate change and water production" (see above).	Medium

Practice/reference	International Application	Application in Australia	Relevance to FWPA Investment Plan
	the US Forest Service to increase habitat.	• Could be considered as a restoration treatment in large tracts of young wildfire regrowth, eg in Victoria.	

4. Estimate of the quantum of gains achievable in Australia

Achievable gains in the native forest sector can be broadly categorised under four themes: *increased social acceptance, productivity, sustainability credentials and industry capacity* (FWPA Strategic Plan 2017-2022). Some key national and international trends are relevant when considering likely gains under each of these themes.

- A worldwide trend for society to demand its native forests (natural and semi-natural forests) particularly on public land, to be managed for resilience to changes in climate and for a multitude of products and services. Outside of large ecological reserves, timber is a component, but not necessarily a major one, and society further demands that it be managed in a way that does not impact other conservation values (Ashton and Kelty 2018). There has been a movement away from even-aged systems and plantations towards stands and their arrangements that are both spatially and temporarily more complex in structure and composition. This means a greater reliance on natural regeneration methods and management approaches that imitate natural disturbance patterns and processes (eg. Attitill 1994; Baker and Read 2011; Messier, Puettemen and Coates 2013). This means a greater reliance on foresters, and management agencies, with a strong silvicultural and ecological knowledge who can craft flexible silvicultural prescriptions that are sensitive to variability in site, topography, hydrology, soils and interactions with disturbance and climate regimes (Ashton and Kelty 2018). However, some would argue that wealthy countries like Australia should forego all timber production from native forests and source their timber products from plantations (and from forests elsewhere).
- At 30 June 2016, the asset value of wood ('standing timber') in Australia's production native forests was estimated by the Australian Bureau of Statistics as $1.8 billion, and the asset value of wood ('standing timber') in Australia's commercial plantations was estimated as $10.2 billion (MPIGA and NFISC 2018)
- Plantation expansion in Australia has now ceased. In fact, the plantation hardwood estate reduced by 2% for over the most recent period reported in Australia's State of the forest report (MPIGA and NFISC 2018). Over the that period, the plantations contributed 8% of Australia's supply of hardwood sawlogs, although they are now the main source of most other wood products.
- Market demand for many native forest products has improved over the last five years, assisted by the reduction in the foreign exchange rate against the US dollar, which increased the commerciality of exported forest products, including manufactured forest products as well as largely unprocessed products such as peeler logs, woodchips, and potentially wood for bio-energy. The increased sale of lower grade material, sometimes described as 'residues', from native forest provides a significant opportunity to increase the productivity and value of the

native forest estate if social acceptance, sustainability credentials and industry capacity can be enhanced.

- The social acceptance of native forestry is ultimately determined through state and national politics. It can also be informed by the area of native forests that meets forest certification standards that include social acceptability indicators. At June 2018, a total of approximately 8.9 million hectares of native forests and plantations were certified for forest management under either the Responsible Wood Certification Scheme or the Forest Stewardship Council scheme (MPIGA and NFISC 2018). On the likely assumption that almost all of Australia's plantations are certified then the area of certified native forests is around 6 million hectares, which is primarily on public land.
- Sustainability credentials are demonstrated through adherence to national policy and state regulations, voluntary commitments through forest certification schemes and through performance against credible measurement and monitoring programs. All state and national Government have legislation that supports the sustainable management of Australia's forests. Codes of forest practices vary in their legal status and coverage, but generally provide specific operational guidance for sustainable forest management practices in public and private forests available for wood production. The ability to measure, monitor and report on forests varies considerably by tenure. The most comprehensive information continues to be available for multiple-use public forests. Significant gaps in data collection and monitoring remain for private native forests (MPIGA and NFISC 2018)

The potential for silviculture RDE to improve productivity in timber volume terms from the native forest estate is limited because of modest growth rates and a management approach based on natural processes, although some opportunities do exist. Particular examples are:

Increased thinning of regrowth (particularly in Tasmania and Victoria). The Young Eucalypt Project (Kerruish and Rawlins 1991) estimated about 100 000 ha of regrowth forest in Tasmania and Victoria was suited to commercial thinning. Current estimates are unavailable. While much of the former area was thinned, additional areas of regrowth have been created after clearfelling operations (at a rate of at least 5000 ha per year) and as a result of bushfires, although for a decade from 1996 much of the clearfelled area in Tasmania was converted to plantations. The average annual rate of thinning over this period has been less than 2000 ha per year so it seems likely that the current area of regrowth suitable for thinning is still of the order of 100 000 ha. The area thinned has been limited by high planning and supervision costs and weak markets for thinnings, although the markets have recently improved. LaSala et al (2004) (see Appendix 4) showed that commercial thinning at age 25-40 years increased sawlog mean annual increments, and net present value, over unthinned stands when compared at 65- and 80-year

rotations. This finding may be even more favourable if recently developed markets for peelers from thinnings were taken into account.

Improve silvicultural uptake and productivity in high-graded private native forests in southern Queensland and northern NSW. There is great potential to improve the hardwood timber production from private native forests, given their large extent (i.e. over 2 million ha of forest mapped as potentially harvestable in southern Queensland and 3.4 million ha on the north coast of NSW) and current poor productive condition (Jay 2017; Cameron et al 2019, Lewis et al in prep). Based on recent sawmill surveys in southern Queensland, the private native forest resource contributes approximately 208 900 m^3 of hardwood sawlog and an additional 18 100 m^3 of pole products each year. On the north coast of NSW harvesting contractors estimated that approximately 274 950 m^3 of private native forest logs are sold each year (Jamax Forest Solutions 2018). Potential future sustainable annual yields from private native forests in southern Queensland were estimated at between 150 000 m^3/y and 600 000 m^3/y, depending on the level of landholder participation in timber production and application of silvicultural treatments within their forests. As an example, if 40% of private native forests were managed for timber production and 30% of these were silviculturally treated, private native forests are predicted to be able to sustainably supply 368 000 m^3/y (Lewis et al in prep). That is 10% more log volume than Crown and private forests in Queensland combined are supplying to the industry at present.

Restored productivity to overstocked stands of jarrah forest. The mid-term review of WA's Forest Management Plan 2014-2023 identified that the forest health and productive capacity objectives for jarrah forests were not being fully met because of the excessive retention of unmarked and unsaleable trees (Parks and Conservation Commission 2018). The Forest Products Commission seeks to better utilise the available material through expanding access to markets for other bole (non-sawlog) volume, the application of new technologies and processes to reduce production costs and undertake trials of suitability for various engineered wood products. At this stage the areas of low productivity and the potential for improvement have not been reported. This issue is somewhat similar to dry forests on private land in Queensland where current sawlog increments of less than 1 m^3/ha/y are likely to be doubled if markets for other bole volume can be developed.

Optimising silviculture for northern NSW forests. The NSW Regional Forest Agreements Implementation Report 2004-14 (NSW EPA 2017) indicates several operational and productivity issues associated with implementing Australian Group Selection in public native forest in northern NSW. In tall forests prescribed gaps of maximum size of 0.25ha are not providing sufficient light for shade-intolerant eucalypts such as blackbutt (*Eucalyptus pilularis*) and gaps are rapidly colonised by mesic understorey species as well as more shade-tolerant eucalypt species. This has resulted in a shift away from Australian

Group Selection silviculture towards heavy Single Tree Selection treatments, but this has raised concerns by the environmental regulator that objectives to mitigate environmental concerns may not be met. This issue combines science, social and definitional aspects and may be assisted by additional silvicultural trials or a review of existing research, including that by Kinny, McElhinny and Smith (2012) which recommended gaps of at least 1 ha.

The potential to improve productivity from investments in silviculture RDE are not without risk, especially across large native forest estates that are subject to bushfires, pest and disease out breaks and climate change. Hence the program of research proposed below includes investments to avoid losses from key risks.

4a Estimate of the quantum of gains achievable in Australia from 2019 to 2023

Projects to improve productivity of native forests generally require long-term sustained effort to achieve measurable change. Shorter term productivity benefits can accrue from efficiencies that use new technology to reduce costs and increase occupational safety, such as by developing remote sensing applications to determine regeneration success. The projects recommended for implementation for 2019 to 2023 in Table 7 aim to deliver long-term benefits but are also designed to give early rewards for the investment made. Table 7 also includes projects designed to increase sustainability credentials, social acceptance and industry capacity. Appendix 5 provides justifications for these projects and outlines anticipated benefits.

Table 7. RDE projects for increasing productivity, sustainability credentials, social acceptance and industry capacity for the period from 2019/20 to 2023/24.

	Project Title	Key points
Theme: Increasing productivity (or avoiding losses)		
1	Commercial thinning guided by remote sensing	• Commercial thinning is now a significant practice in NSW Tas, WA and Vic State native forests. • LiDAR and Digital Aerial Photography, and UAV and microsatellite technology offer great potential to better target thinning operations and record outcomes. • Remote sensing can reduce field-time of operations staff, improving efficiency and safety. • Containing costs of harvesting and monitoring, through better information on ground and stand conditions, will improve opportunities for better contractor management (ie compliance with silvicultural specifications – stems per ha and distribution of habitat elements) leading to better reporting/transparency. • Better selection of retained stems will improve future production of high value timber, and better forecasting of future yields. Anticipated gains: Cost savings
2	Remote sensing regeneration success	• There is a need to reduce cost and OHS issues associated with regeneration surveys. • LiDAR and Digital Aerial Photography, and UAV and microsatellite technology offer great potential to determine regeneration success. • Research is needed to develop the image analysis techniques and timing of imagery according to seasonal variation. • Most applicable for growers who routinely do regeneration surveys (FPC, STT, VicForests) Anticipated gains: Cost savings
3	Integrated harvesting of high-graded native forests	• The need is most evident in Qld, where productivity levels could be lifted from <1 to 2 m^3/ha/y through better silviculture and development of markets for small wood (bioenergy, peelers, pulp). • The project is also relevant to NSW private growers. • Research is needed to determine how much small wood can be harvested without depleting soil nutrients. • Appropriate silvicultural prescriptions need development to increase productivity and provide for retention of nutrients and coarse woody debris habitat. Anticipated gains: • Increased sawlog increments • Immediate revenue from residue sales
4	Options for improving jarrah productivity	• The excessive retention of unmarked trees, due to insufficient access to markets for jarrah and marri other bole volume has resulted in significant areas of overstocked dry forest with low productivity.

	Project Title	Key points
		• Overstocked forests in dry landscapes can be subject to episodic mortality from drought and use scarce water that would otherwise be available for maintaining a healthy landscape. • This project would document the extent of the area affected, use inventory data to quantify current and potential growth rates, and identify options to reduce wood production costs and undertake trials of suitability for various engineered wood products. • This issue is somewhat similar to dry forests on private land in Queensland where current increments of less than 1 m^3/ha/y are likely to be doubled if markets for other bole volume can be developed. Anticipated gains: Increased water availability for ecosystem Increased sawlog increments
5	Evaluation of previous productivity investments	• This project would aim to identify a subset of well-designed legacy trials that have not been fully analysed, may be worthy of further measurement and should be reported. • Analysis and write-up of trials from the 1990s (CSIRO-Mike Connell) and the 2000s (Forestry Tasmania-Ann LaSala) would inform long-term responses to thinning. The recent PhD thesis by Soraya (ANU Supervisor Cris Brack) could provide a basis for papers on the CSIRO plots. • Other long-term trials may merit final measurements and publication. Anticipated gains: Knowledge to inform current or potential thinning programs
6	Understanding needs of private native forest growers	• This project would seek to determine the values, aspirations and silvicultural preferences of private native forest growers? The focus of the project would be private native forest owners in Queensland, New South Wales and Tasmania which are the main sources of timber from private land. • The *State of the forests report 2018* indicated knowledge of private native forest owners' aspirations as a key gap in predicting wood flows from the private native forest estate. • Objectives for private native growers are different to public native forest growers and their attitudes and aspirations are important to maintaining a significant supply of forest products from the private forest estate. Anticipated gains: Increased knowledge for private native forest support agencies to provide assistance to encourage sustainable forest management
7	Climate-adapted protocols for provenances and species	• The effect of rising temperature is expected to cause species range shifts that are most likely to be southerly or to higher elevations. Native forest communities are likely to experience local extinctions and the introduction of new species and higher potential for diseases, weeds and pests as well as an increase in wildfire frequency that will increase tree mortality and, in young regenerating stands, jeopardise forest re-establishment. • Native forest growers use seed-zone systems to prescribe the use of on-site or in-zone seed for regeneration. However, climate change may well dictate that alternative provenances, and perhaps even

	Project Title	Key points
		alternative native forest species, are better matched to future site conditions. • This project would develop measures to improve provenance decision-making, including embedding provenance trials, developing dynamic, evidence-based provenance policies; and establishing stronger research–grower collaborations to facilitate the adoption of research outcomes. • This is most relevant to managing provenance selection for growers who apply broadcast sowing but is also relevant to growers who use supplementary planting as part of their regeneration treatments. Anticipated gains: Climate-adapted seed provenance protocols. Avoided losses
8	Decision support apps for harvest planning	This project would develop a mobile app to assist forest planning and reduce the cost of preparing timber harvesting plans. • Preparation of timber harvesting plans for native forests is time consuming and expensive. • About 500 such plans might be prepared annually. The mobile app would access existing environmental, productivity and regulatory data sets in order to assist forest planning (especially for private growers). This could include: 1. Landsat imagery, NCAS productivity and disturbance history. 2. Habitat and regulatory requirements/management constraints. 3. Inventory system and management advice. Anticipated gains: Cost savings
		Theme: Increasing sustainability credentials
9	Guidelines for responsible recovery of timber from burnt forests	Bushfires have always been part of the forested landscape and may be increasing due to climate change. When areas designated for wood production are burnt efforts are usually made to recover the fire-damaged timber. The science literature by ecologists and hydrologists highlights the negative aspects of salvage logging, often without acknowledging the benefits. • Negative impacts of the salvage harvesting can be reduced with responsible operating procedures, including the retention of islands of less burnt forest. • The suitability of fire-damaged wood for particular uses (sawn, engineered wood products, pulp) needs to be better understood by growers and customers. A range of often-conflicting views on suitability are advanced by customers. While much has been learnt about timber properties and markets, very little of that knowledge has been made available to guide future salvage harvesting operations. • This project would engage a consultant, or consultants, to review all relevant literature and document what growers know, and what they need to know, about responsible salvage harvesting drawing on experiences from Victoria (2003, 2006, 2009 bushfires), WA (2015 and 2016 bushfires) and Tasmania (2016 and 2019 bushfires) and with particular reference to: OHS, habitat retention, water quality, market (wood quality and timing) and assisted regeneration requirements. The work should consider regulatory and certification requirements.

	Project Title	Key points
		Anticipated gains: Guidelines for responsible recovery of timber from burnt forests. Optimising salvage of burnt timber to markets.
10	Coarse Woody Debris prescriptions for high residue removals	Coarse woody debris (CWD) is the standing and fallen dead wood in a forest and serves an important role in ecosystem functioning, especially as habitat for invertebrate fauna. • Studies in Tasmania, partly stimulated by potential biomass energy projects, indicated that CWD levels in wet eucalypt forests are very high. • Less is known about CWD levels and dynamics in dry forests. This project is a high priority for WA jarrah where prescribed burning may interact over time to deplete CWD retained at harvest events. • This project also has relevance to any native forests where a high level of residue removal is planned or undertaken. • This project would review data of CWD levels in harvested and unharvested forests for major commercial native forest types; establish additional plots where information is lacking; develop simple models to indicate CWD levels over time; and develop prescriptions for CWD retention where minimum retention levels would not otherwise be assured. Anticipated gains: Practical prescriptions for CWD retention after harvesting where minimum retention levels would not otherwise be assured.
11	National workshop on long-term monitoring	Growers need to know how resilient their forests will be to harvesting, wildfires, disease and climate change, which requires long-term monitoring. They also need effectiveness monitoring to determine if their management actions are working (as per regulatory and certification requirements), particularly for threatened species. • Many agencies have an interest in long-term monitoring, but few are prepared to fund it (at least not without partners). The Terrestrial Ecological Research Network (TERN) Australia is the lead agency for fostering long-term research sites but needs contributors. • Growers could play a useful role by asking FWPA to facilitate and co-fund a national workshop to determine "What long-term monitoring worked, and what didn't? How should we best go forward, given likely budgets and resources?" • The workshop should particularly consider monitoring outcomes and futures for the FORESTCHECK, Warra LTER and Victorian Silvicultural Systems projects. • Workshop presentations could be lodged on a website and a short synthesis of proceedings and recommendations should be prepared for FWPA and potential long-term site partners. Anticipated gains: • Increased awareness of, and commitment to, significant long-term monitoring efforts. • Identification of cost-effective monitoring approaches to meet regulatory and certification requirements.
Theme: Increasing Public Acceptance		

	Project Title	Key points
12	Reduced reliance on clearfelling and high intensity burning	Clearfelling with high intensity burning is now mainly confined to commercial wet eucalypt forests in Tasmania and Victoria with dense understoreys. Despite a marked reduction in clearfelling over the last two decades, and the inclusion of significant retention at the landscape level, the practice is still somewhat controversial. The smoke nuisance posed by high intensity burns, and concentrated in a narrow burning window in Autumn, is a significant social acceptance issue. • Variable retention (VR) silviculture is a system developed as an alternative to clearfelling, and with the explicit goal of maintaining species, habitats and structural features at the stand level. About 200 ha per year of variable retention are currently applied annually, mainly in Tasmania (MPIGA and NFISC 2018). The silviculture is now reasonably well developed (Scott et al 2011) but difficult to implement. • More widespread adoption of VR is hampered by the difficulty of reducing high slash loads, primarily through burning, while maintaining patches of retained forest within harvest boundaries. • A program of continuing to reduce reliance on clearfelling and high-intensity burning is attractive because it addresses social and biodiversity concerns. • The most likely "game changer" for moving away from clearfelling and high-intensity burning to more socially acceptable systems (small-patch clearfells, VR or uneven-aged silviculture) would be strong markets for residues. This would allow slash-loads to be considerably reduced and burnt in small heaps under cooler conditions and over a much longer season. • While this project is fundamentally important, it is recommended that a large research program is not currently needed, at least until markets for residues, or alternative slash-busting technology, become available. However, two significant questions can be explored in 2019-2023 with moderate funding, as described below: • A. Understanding the importance of burnt seedbeds for long-term vigour of eucalypts. • B. Understanding the public's preference for alternative silviculture approaches in forest landscapes. Anticipated gains: Clarification of the importance of burning for eucalypt productivity in the long-term. Better understanding of public preferences for alternatives.
13	Community engagement approaches for native forest growers	A handbook was developed to guide community engagement for plantation managers (Dare, M., Schirmer J. & Vanclay, F. 2010. *Handbook for operational community engagement within Australian plantation forest management*). • While some of the social issues are common between native forest and plantation growers, many are more prominent with native forestry, eg. around biodiversity, smoke management, use of public native forests.

	Project Title	Key points
		• This project would review community engagement approaches currently or potentially used by native forest growers, with a focus on increasing social acceptance as well as meeting certification and regulatory requirements. • It would develop a handbook for operational community engagement for Australian native forest growers. Anticipated gains: A handbook for operational community engagement for Australian native forest growers
Theme: Increasing Industry Capacity		
14	Future silviculturists: NFS Interest Group and undergraduate support	Native forest growers need a limited number of silviculturists who have practical knowledge and can contribute to, or interpret, scientific literature. There is a declining supply of silviculturists in Australia. • ANU, Melbourne and Southern Cross universities now have healthy enrolments in forestry related courses which have been rebadged as ecosystem management to downplay the active forestry elements. Students that are interested in silviculture and active management are mostly from overseas countries, eg China and Indonesia, and usually return. • A Native Forest Silviculture Interest Group (NFSIG) of grower and research provider representatives is proposed to advise on the implementation of FWPA's Investment Plan and to assist with adoption of research products. The NFSIG would have at least one annual teleconference to review progress, conduct a field-based mid-term review of the outputs and success of the research program and advise FWPA on rollout of the second phase of the Investment Plan. • FWPA could award a $3k annual award for the best honours thesis on native forest silviculture from an Australian university. This would indicate grower support and help identify a cohort of new graduates with an interest and talent for native forest silviculture. Anticipated gains: The Native Forest Silviculture Interest Group would help guide and deploy the research products from this Investment Plan. An annual award for the best honours thesis would help identify a cohort of new graduates with an interest and talent for native forest silviculture.
15	Standardised silvicultural classification and terminology	Silvicultural terminology is highly variable across jurisdictions and not aligned with international standards. • The sloppy use of silvicultural terms causes misunderstanding within the forestry profession and in dealings with the general public. • This project would review silvicultural terminology used for native forestry in Australia and develop a standardised classification and terminology. Anticipated gains: A standardised classification and terminology for Australian native forestry.
16	Training materials (procedural manuals/ videos/apps) for native forest growers,	Growers need employees and contractors to be trained sufficiently to achieve best outcomes for the forests they are growing, eg prescriptions for thinning.

	Project Title	Key points
	employees and contractors)	• Growers are increasingly turning to technical training providers to train field foresters, eg in Certificate III in Forest Growing and Management. • Training providers need good materials on native forest silviculture to deliver effective training. This may include manuals and videos. • This project would have two phases: 1. Engagement of an experienced silviculturist to liaise with public native forest growers, private native forest grower support agencies, universities and VET training providers to identify a prioritised list of current and potential training materials. 2. Development of new or revised training materials identified in phase 1 within budget constraints. Anticipated gains: • A prioritised list of training material needs. • At least one new or improved training material for each state by 2023.

5. Barriers to achieving potential gains

As indicated in FWPA's strategic plan 2017-2022 "For the native forestry sector to be successful it must be able to overcome its capability constraints. The sector will need to embrace more fully a culture of diversity and innovation, including knowledge generation and adoption, technical transfer, skill development, continuous improvement and international best practice and do these things in a consistent, continuous and sustained manner. "

This Investment Plan has identified a research program, within a realistic budget, that will improve knowledge and systems and mitigate risks. Three potential barriers to achieving these gains, in addition to those mentioned above, in delivering this plan are potential deficiencies in:

1. Development of detailed project briefs and support and continuing engagement by forest growers.
2. Expertise in native forestry among service providers.
3. Expertise and capacity among forest growers to deploy research developments.

Development of detailed project briefs and support by growers. The native forest sector is more disparate in its outlook, particularly for research, than the plantation sector which has become conditioned to collaborate through decades of working together through the Cooperative Research Centre process and on FWPA sponsored research. The successful implementation of this research plan will require a high level of engagement between native forest growers and research providers if projects are to genuinely deliver gains across state and tenure boundaries. The first challenge will be for the potential proponents named in Appendix 5 (or their nominees) to commit to developing detailed projects, with appropriate contributions of cash and in-kind support. In many ways the in-kind support will be more crucial in focussing the research on field forestry matters and exposing the researchers to the operational issues that influence the relevance of the intended research solution. It is likely that a level of co-ordination from FWPA will be needed to convene potential research proponents and assist them to develop implementable research briefs. The proposed Native Forest Silviculture Interest Group should also provide an opportunity for individual members, and collectively at an annual meeting/teleconference, to inform the relevance of individual research projects.

Expertise in native forestry among service providers

Public native forest growers have outsourced their research functions to other state agencies and universities, which has delivered some efficiencies in delivering focussed research but has diminished the strong knowledge and extension role provided by in-house researchers of previous times. Appendix 6 provides a list of research organisations that contributed to research in native forest silviculture

reported in *Australian Forestry* over the last decade. While some of these providers no longer exist, it is likely that there is still (just) enough expertise in native forest research to deliver the projects listed in this investment plan. In some cases, it may be necessary to engage past staff of grower organisations or research providers to contribute to the work. The use of international research providers is probably not required, unless an Australian provider cannot be identified, although collaboration or co-supervision by overseas researchers can be very beneficial for all parties. One area that may require international input may be in the use of UAVs and digital aerial photography for silvicultural operations in native forests. It is noteworthy that Department of Forest Resource Management at the Faculty of Forestry at the University of British Columbia has recently assessed the use of digital aerial photography and unmanned aerial vehicles to assess regeneration success (Goodbody et al 2018).

Expertise and capacity among forest growers to deploy research developments.

This is more likely to be a risk for projects intended for deployment by private forest growers (projects 3, 6 and 8). Uptake of research gains identified by project 3 may well be hard to achieve, especially in the absence of markets for residual wood. Transfer of new information to farm foresters will need to be a particular focus for the Queensland Department of Agriculture and Fisheries and for Private Forest Services Queensland. Similarly, the development of apps to assist preparation of timber harvest plans could easily fall short of making the intended gains without promotion by private native forest grower support agencies like Local Land Services in NSW and Private Forests Tasmania.

It is likely that most projects under the productivity theme will enjoy a strong level of deployment by native forest growers because the research products will improve their economic position. Projects under the sustainability and social acceptance themes are also likely to be deployed with commitment by growers being assisted by regulatory and forest certification requirements.

Projects under the capacity theme may be less immediately attractive to native forest growers because, until now, the issues have been able to be deferred for consideration at a later time. Given the rapidly dwindling capacity in native forest silviculture to underpin the sustainable supply of 1.1 million m^3/y of hardwood sawlogs from public land, it is argued that these projects are critically important and should also enjoy strong grower support.

6. An outline of the priority RDE needed from 2024/25, and beyond as an outlook to achieve the potential gains.

The priority RDE needed from 2019/20 to 2023/24 has been described as 16 projects categorised under 4 themes in Table 7 and Appendix 5. Table 8 below provides brief descriptions of a further 14 potential projects to indicate research priorities for the period from 2024/25 to 2028/29.

Table 8. An outlook of likely RDE needed to increase productivity (or avoid losses), sustainability credentials, social acceptance and capacity for the period from 2024/25 to 2028/29.

	Project Title	Key points
Theme: Increased productivity (or avoided losses)		
1	Thinning prescriptions for value, rather than volume	• Current thinning prescriptions are based on maintaining stand increment and thinning stems that would otherwise be lost to mortality. They typically prescribe thinning ash-forest stands to about 250 stems/ha at age 30. • To maximise sawlog growth, thinning should probably be done to lower stocking, which might also increase the commerciality of the thinning. • Thinning prescriptions should also take account of peeler production at thinning and final harvest to maximise value.
2	Use of Unmanned Aerial Vehicles for silvicultural operations	• Unmanned aerial vehicles are getting cheaper and can lift heavier payloads. • Larger UAVs can potentially be used for silvicultural operations such as aerial sowing. Sowing a typical coupe requires a sowing mass of less than 50 kg. • Aerial ignition of prescribed burns is also a possibility although quality controls would need to be developed and strictly applied. • The technology and the necessary safety and quality standards for such operations need to be evaluated.
4	Silvicultural prescriptions for mechanical fuel reduction in strategic zones to avoid bushfires	• A current Bushfire Fuel Load Reduction Trials project will likely identify priorities for development and implementation. These may include short rotations with high residue removal in strategic zones. Depending on scale, the silvicultural implications for the treated areas and for other values will need to be identified and managed appropriately.
5	Development of LiDAR for inventory and growth estimation for uneven-aged forests	• Many silvicultural decisions require good inventory and growth estimation. • This is especially the case as Australian silviculture trends to more uneven-aged management. • Inventory costs can be reduced by LiDAR imputation but applications for estimating growth in uneven-aged stands need further development.

	Project Title	Key points
6	Growth simulators for guiding silvicultural manipulations at a strategic level	• Growers needs have been met by simple timber yield models, but future demands might require forecasting a broader range of outputs. • Process-based growth simulators have not yet been developed for Australian native forests although 3PG2 has been calibrated for natural jarrah and karri regrowth and provided a basic approach to investigate effects of climate change. Outputs have been limited to stand averages and total volumes, with density dependent mortality only. There has also been work at Murdoch University using CABALA on a jarrah stand. • The technology to capture data inputs for simulators is getting cheaper (LiDAR, DAP and UAVs). • Growers now need forecasting of a broader range of outputs (e.g. timber, water, habitat) than can be obtained from current simple yield models. • A range of useful simulators have been developed to model complex stand management interventions in the US, Canada and Germany. • Similar simulators should be developed for Australia.
7	Apps for guiding silvicultural manipulations at a tree level	• Until recently, decisions about which individual trees to harvest have been based on stand and tree "averages" – the average competition in the stand (measured by stand basal area or stocking), average site quality (average of the tallest trees), and average defect and conversion rates. Even estimates of regeneration potential are based on average opening sizes. • New technology, including terrestrial and drone-mounted LiDAR, digital colour photography and Artificial Intelligence offer opportunities to optimally manage at an individual tree level. • This project would integrate the tree-level and "distance dependent" data (i.e tree map) from LiDAR or digital photography into a mobile app / Augmented Reality that estimates the impact on surrounding vegetation of every tree (potentially) harvested and improved product estimation.
8	Using digital aerial photography (DAP) for species identification, habitat mapping and automated mapping for species and forest health surveillance	• DAP-derived canopy imagery can be very powerful and provides spatially-referenced point cloud and colour information. • This technology may allow automated mapping for high value species (e.g. white cypress pine) and habitat features (e.g. eagle nests, large trees with hollows) as well as monitoring forests for changes in condition through analysis of digital mapping conducted over a time series. • This project would develop and test this technology for a range of priority applications identified by native forest growers.
9	Automated systems for cost-effective biodiversity monitoring in native forests	Under forest certification schemes, responsible forest managers are required to conduct, or contribute, to biodiversity monitoring, particularly for threatened species. These programs can be very expensive, often quite subjective and data are difficult to interpret. A range of automated biodiversity monitoring tools are under development (eg. machine learning of bird calls) but research is needed to identify systems which have most application for use by native forest growers.

	Project Title	Key points
		Theme: Increasing sustainability credentials
10	Understanding nutrient balances for sustainable biomass harvesting	• Harvesting of native forest residues for bioenergy is expected to increase over the next few years but the nature of the harvesting, affected forest and soil types and scale of the harvesting is not well known. Generalised inferences from plantation operations are that operations that retain leaves and branches on site are unlikely to suffer significant nutrient depletion, especially if left unburnt. • Specific studies will be needed to understand nutrient balances under actual high-residue removal operations for a range of forest, soil and forest re-establishment practices.
11	Variable-density thinning for habitat enhancement	• This may be warranted if commercial thinning reaches a scale where habitat values could be compromised. • It could also be considered as a restoration treatment in large tracts of young regrowth, particularly after major bushfires (such as 2003, 2006 and 2009 in Victoria). • Variable-density thinning can also increase resilience to climate change and water production by reducing stand densities without impacting on habitat values.
		Theme: Increasing Public Acceptance
12	Slash treatments to reduced reliance on clearfelling and burning	• While growers are likely to continue to make small reductions in clearfelling and high-intensity burning over the next five years, a large shift is unlikely unless practical, cost-effective and ecologically sound solutions can be found for reducing the large slash loads that result from the large eucalypt crowns and dense understorey in wet eucalypt forests. • The most likely "game changer" for moving away from clearfelling and high-intensity burning to more socially acceptable systems (small-patch clearfells, VR or uneven-aged silviculture) would be strong markets for high residue removal operations. This would allow slash-loads to be considerably reduced and burnt in small heaps under much cooler conditions and over a much longer season. • By 2024 it is likely that markets for residues for bioenergy will have developed and residual slash loads can be significantly reduced. • The feasibility of a major shift away from clearfelling and high intensity burning should be evaluated, supported by operational trials that incorporate low intensity burning and advances in mechanical treatments to reduce residual slash for effective seedbed preparation.
13	How have institutional factors affected the adoption of silvicultural innovations by large native forest growers?	The choice of silviculture should reflect the owner's objectives, provision for regeneration, efficient use of site productivity, risk of damaging agencies (such as bushfire), provision for sustainable yield, optimum use of capital, efficient arrangement of operations, maintenance of desired plant and animal populations and policies about landscapes, scenery and aesthetics. These factors all change over time. • This project would explore how institutional factors have affected the adoption of silvicultural innovations by large native forest growers

	Project Title	Key points
Theme: Increasing Industry Capacity		
14	An authoritative (online) silvicultural text for Australia's native forests	• This project would build on works by Elliott et al (2008), Florence (1996) and Turner et al (2011) as well as the FWPA investments in standardised terminology and classification for Australian silviculture and updated procedural manuals, international silvicultural knowledge and expert input from the Native Forest Silviculture Interest Group to prepare an authoritative (online) silvicultural text for Australia's native forest. • This text would inform practitioners, public debate and national and international state of the forests reporting.

Beyond 2028/29 it is anticipated that native forests will be increasingly regarded as a source of niche products, including high quality sawlogs and timbers for special purposes. Because the proportion of high value sawlogs is usually less than one-quarter of the bole volume of a stand, a focus on high value sawlogs will also require a focus on markets for arisings, in order to maintain forest productivity and health as well as economic production. If markets for low quality wood can be developed, particularly for bioenergy, there should be more interest from private native forest growers to manage parts of their property for ongoing timber production. Hence likely research priorities beyond 2029 should include strategies to identify a stable private native forest estate so that a sustainable yield can be calculated to complement the supply from the public native forest estate and inform investment decisions in processing. Other major priorities should include research on stand management to identify optimum densities for climate change resilience and to mitigate against a likely increase in bushfires and pest and diseases.

7. The anticipated benefits of implementing the required RDE from 2019/20 to 2023/24

The anticipated benefits from implementing the required RDE from 2019/20 to 2023/24 are summarised in Table 9.

Table 9. Anticipated benefits of RDE projects from 2019/20 to 2023/24. (

Project	Anticipated Benefits
1. Commercial thinning guided by remote sensing	Short: savings in planning and compliance costs; savings in harvest costs. Long: increased sustainable sawlog yield.
2. Remote sensing regeneration success	Short: savings in survey and compliance costs; reduced risk to field staff.
3. Integrated harvesting of high-graded forests	Short: increased yield of treated forest. Long: sustainable sawlog yield from private forests.
4. Options for improving jarrah productivity	Short: increased water availability for ecosystem. Long: increased yield of jarrah sawlogs.
5. Evaluation of previous productivity investments	Short: informed thinning programs.
6. Understanding needs of private native forest growers	Short: targeted assistance programs. Long: sustainable sawlog yield from private forests.
7. Climate-adapted protocols for provenances and species	Short: climate-adapted seed provenance protocols. Long: avoided yield losses.
8. Decision-support apps for harvest planning	Short: savings in harvest plan preparation.
9. Guidelines for responsible recovery of timber from burnt forests	Short: increased value from sale of fire-damaged timber. Long: maintain rights to harvest fire-damaged forests.
10. Coarse Woody Debris prescriptions for high residue removals	Short: increased access to responsible bio-energy markets.
11. National workshop on long-term monitoring	Short: cost-effective monitoring approaches to meet regulatory and certification requirements.
12. Reduced reliance on clearfelling and high-intensity burning	Short: Increased understanding of public preferences for alternatives; clarification of the importance of burning for long-term eucalypt forest productivity.
13. Community engagement approaches for native forest growers	Short: handbook for operational community engagement for Australian native forest growers.

14. Future silviculturists: NFS Interest Group and undergraduate support	Short: knowledge transfer from research providers and growers; develop next cohort of silviculturists.
15. Standardised silvicultural classification and terminology	Short: reduced misunderstanding within the forestry profession and the general public.
16. Training materials (procedural manuals/videos/apps) for native forest growers, employees and contractors)	Short: prioritised list of required training materials; at least one new training material for each State by 2023.
Total	

The suggested allocation of RD&E investment across the four themes is:

Increasing productivity	59%
Increasing sustainability credentials	18%
Increasing social acceptance	8%
Increasing industry capacity	15%

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Appendix 1. Stakeholders Consulted

	Contact	Affiliation	Format
Inception Meeting	Jodie Mason	FWPA	teleconference
17/1/19	John Hickey	Consultant	
	Ruth Harvey	FPC	
	John Tredinnick	FPC	
	Brad Winthrop	Midway	
	Jim Burgess	QDAF	
	Suzette Weeding	STT	
	Dean Williams	STT	
	Anne Geary	Vicforests	
	Tim McBride	Vicforests	
Workshop 1. Native Forest Growers			
22/2/19	Jodie Mason	FWPA	FWPA office
	John Hickey	Consultant	FWPA office
	Hamish Webb	DEWLP	FWPA office
	Justin Williams	FCNSW	Teleconference
	Ruth Harvey	FPC	Teleconference
	Kerrie Catchpoole	QDAF	Teleconference
	Tom Lewis	QDAF	Teleconference
	Suzette Weeding	STT	FWPA office
	Dean Williams	STT	Teleconference
	Anne Geary	Vicforests	FWPA office
	Tim McBride	Vicforests	FWPA office
Workshop 2. Growers and Research Providers	Jodie Mason	FWPA	FWPA office
13/3/19	John Hickey	Consultant	FWPA office
	Shaun Suiter	DEWLP	FWPA office
	Ruth Harvey	FPC	Teleconference
	Brad Winthrop	Midway	FWPA office
	Tom Lewis	QDAF	Teleconference
	Suzette Weeding	STT	Teleconference

	Contact	Affiliation	Format	
	Dean Williams	STT	Teleconference	
	Anne Geary	Vicforests	FWPA office	
	Tim McBride	Vicforests	FWPA office	
	Cris Brack	ANU	Teleconference	
	Doland Nicholls	SCU	Teleconference	
	Patrick Baker	UniMelb	FWPA office	
	Simon Murphy	UniMelb	FWPA office	
	Mark Neyland	UTAS	Teleconference	
	Tim Wardlaw	UTAS	Teleconference	
Private Forest Grower Support Agencies	Martin Moroni	Private Forests Tasmania		
	Rob Smith	Private Forests Tasmania		
	Sean Ryan	Private Forest Services Queensland		
Researchers	Patrick Baker	School of Ecosystem and Forest Sciences, Melbourne University		
	Lauren Bennet			
	Rod Keenan			
	Rebecca Ford			
	Simon Murphy			
	Craig Nitschke			
	Sue Baker	School of Natural Sciences and ARC Centre for Forest Value, UTAS		
	Mark Neyland			
	Tim Wardlaw			
	Martin Rayner	Department of Biodiversity, Conservation and Attractions, WA		
	Tom Lewis	Department of Agriculture and Fisheries, Qld		
	Doland Nicholls	Southern Cross University, NSW		
	Cris Brack	Fenner School, Australian National University, ACT		
Other	Ken Felton	Silviculturist (retired)		
	Stephen Walker	Forest Practices Authority		
	David Mannes	FCNSW		

Appendix 2. FWPA Investments (from 2009 to 2018) in native forest silviculture RD&E, listed in order of report publication date.

Title/ Project No	FWPA Report/ Date	Findings/ outcomes
Carbon stocks and flows in native forests and harvested wood products in SE Australia. PNC285-1112	Ximenes F, Bi H, Cameron N, Coburn R, Maclean M, Sargeant N, Mo M, Roxburgh M, Ryan M, Williams J and Boer K (2016) Carbon stocks and flows in native forests and harvested wood products in SE Australia.	1. Tracked the fate of C from representative native forests in New South Wales (NSW) and Victoria (VIC), in forests managed for multiple use ("production") and conservation only. 2. Relative differences in the GHG balance of production and conservation scenarios do not warrant policies that aim to halt native forest management for wood production. 3. The work highlights the potential for further industry development that can be coupled with an improved GHG outcome, involving increased use of biomass for bioenergy, value-adding of processing co-products and changes in waste management.
Scoping study for an FWPA investment plan for native forest management	Sands R (2014). Research and Development for Native Forest Management and Wood Supply (Unpublished)	The terms of reference for this scoping study were that any recommendations in a Research and Development Plan should be (a) not regionally based and (b) not transferrable from plantation research. In most cases these criteria could not be met. Accordingly, there will be no Plan as such but there are some issues that merit consideration. There is poor understanding between stakeholders of what could be in their common interests. Targeted workshops could share research successes and failures and canvass efficiencies and national agreed standards where appropriate. These workshops could have the added advantage of determining the commitment of stakeholders and the availability of research providers. A workshop based on the soon to be terminated Warra long-term trial in Tasmania would be a valuable knowledge sharing exercise and could include FORESTCHECK in Western Australia, the Central Highlands in Victoria, OZFLUX and other long-term sites. One important research question might be whether there are less expensive and quicker ways of obtaining this information rather than expensive and long-term trials. This workshop could share expertise in monitoring and in resource assessment and could also look at silvicultural procedures such as ecological thinning and variable retention. Another issue that was shared over many jurisdictions was concern about the deteriorating wood quality of the smaller stems coming on stream. Research looking at thinning, addressing degrade and developing processing

Title/ Project No	FWPA Report/ Date	Findings/ outcomes
		technologies for these smaller poorer stems would be useful. Apart from socio/political issues, stakeholders considered the best economic use of residues to be their most significant economic problem. This is already being vigorously pursued in wider initiatives that include forest plantation and agricultural residues as well.
Contribution of CAR reserves to mature forest biodiversity in production forest landscapes. PNC142-0809	Wardlaw T, Grove S, Balmer J, Hingston A, Forster L, Schmuki C and Read S (2012). Persistence of mature forest biodiversity elements in a production forest landscape managed under a Regional Forest Agreement	Used multi-scaled plots in a 1120 km^2 region to test the extent to which (i) the biodiversity in mature eucalypt forest would be independent of the intensity of disturbance in the surrounding landscape and (ii) that the recolonisation of silvicultural regeneration by mature-forest species would be independent of the intensity of disturbance in the surrounding landscape. Suggested some simple metrics and other planning tools that could guide planning in relation to the spatial and temporal arrangement of mature forest in production-forest landscapes. Concluded that, in the case of this region, a network of reserves within a large production matrix (as fostered by RFAs) had so far been effective in maintaining mature-forest biodiversity for three tested groups: disturbance-sensitive beetles, dense-forest birds and rainforest plants.
Variable Retention Silviculture: A comparison of biodiversity research and management practices between Tasmania, Australia and the Pacific Northwest (WFI awardee: Susan Baker). PGD167-0910	Baker S (2011). Seeking a balance between forestry and biodiversity – the role of variable retention silviculture Insights from western USA and Canada	Variable retention (VR) is increasingly being used worldwide to achieve improved biodiversity and social outcomes compared to clearcutting and other traditional silvicultural systems. It was initially developed in the Pacific Northwest (PNW of USA and Canada and insights from the PNW about operational experience, research, adaptive management, and efforts to improve relationships between timber industry and environmental groups are of broad relevance to forest management in Australia. The system is being used in a wide variety of forest types, including old-growth, second and third-growth forests; and a variety of land tenures including those managed by industrial companies on both public and private lands. This report covers: results from surveys of twelve organizations that are currently implementing VR across western USA and Canada; research and formalized adaptive management programs relating to improving conservation outcomes from silvicultural practices; and, examples of successful collaborations that have settled long-term conflicts between timber industry and environmental groups, resulting in improved conservation outcomes and continued timber production. Using VR had generally achieved the social and ecological objectives, and organizations were planning on continued implementation. However, there was uncertainty over long-term ecological outcomes, emphasising the need for long-term biodiversity research.

Title/ Project No	FWPA Report/ Date	Findings/ outcomes
Review of the science of public native forest management for sustainable timber management in Victoria. PRC147-0809	Turner J, Flinn D, Lambert M, Wareing K and Murphy S. (2011). Management of Victoria's Publicly-owned Native Forests for Wood Production: A Review of the Science Underpinning their Management.	A review of the science that underpins the management of publicly-owned native forests for timber production in Victoria: including productive capacity; protection of the environment (biological diversity, ecosystem health and vitality, soil and water resources and global carbon cycle); and, ensuring that there is no loss of opportunity for future generations. The review considered six broad forest types, namely Alpine Ash, Mountain Ash, High Elevation Mixed Species, Low Elevation Mixed Species, River Red Gum and Box-Ironbark. Extensive valuable research has been undertaken in the forests of Victoria. Large amounts of research and technical information is held within various Government and University Departments, often not in a readily accessible form. The information needs to be made more accessible in published form at both the basic information level and in synthesised or reviewed form similar to this focused review. Projects have been commenced and a great deal of preliminary information has been produced in the early phases, but long-term data are lacking. Apart from on-going monitoring of strategically important Silvicultural Systems Project component studies, the study of the ecological impacts of fuel reduction burning in the Wombat State forest should continue to have a high priority in the future. Another study that must be accorded the utmost priority is the long-term ecological monitoring of the Variable Retention Harvest System (VRHS) trials.
Growth predictions in private spotted gum dominant forests in Queensland and N NSW to provide landholders with silvicultural tools to assist them in spotted gum stand management. PNC075-0708	Lewis T, Osborne D, Hogg B, Swift S and Bristow M (2010). Tree growth relationships and silvicultural tools to assist stand management in private native spotted gum dominant forests in Queensland and northern New South Wales.	Spotted gum dominant forests occur from Cooktown in northern Queensland (Qld) to Orbost in Victoria and are commercially very important; with spotted gum the most commonly harvested hardwood timber in Qld and one of the most important in New South Wales (NSW). The private native forest resource in southern Qld and northern NSW is a critical component of the hardwood timber industry and currently half or more of the native forest timber resource harvested in northern NSW and Qld is sourced from private land. However, in many cases productivity on private lands is well below what could be achieved with appropriate silvicultural management. This project provides silvicultural management tools to assist extension staff, land owners and managers in the south east Qld and north eastern NSW regions. The intent was that this would lead to improvement of the productivity of the private estate through implementation of appropriate management. The other intention of this project was to implement a number of silvicultural experiments and demonstration sites to provide data on growth rates of managed and unmanaged forests so that landholders can make informed decisions on the future management their forests. To assist forest managers and improve the ability to predict forest productivity in the private resource, the project has developed: • A set of spotted gum specific silvicultural guidelines for timber production on private land that cover both silvicultural treatment and harvesting. The guidelines were developed for extension officers and property owners.

Title/ Project No	FWPA Report/ Date	Findings/ outcomes
		• A simple decision support tool, referred to as the spotted gum productivity assessment tool (SPAT), that allows an estimation of: Tree growth productivity on specific sites. Estimation is based on the analysis of site and growth data collected from a large number of yield and experimental plots on Crown land across a wide range of spotted gum forest types. Growth algorithms were developed using tree growth and site data and the algorithms were used to formulate basic economic predictors. Pasture development under a range of tree stockings and the expected livestock carrying capacity at nominated tree stockings for a particular area. Above-ground tree biomass and carbon stored in trees. • A series of experiments in spotted gum forests on private lands across the study area to quantify growth and to provide measures of the effect of silvicultural thinning and different agro-forestry regimes. The adoption and use of these tools by farm forestry extension officers and private land holders in both field operations and in training exercises will, over time, improve the commercial management of spotted gum forests for both timber and grazing. Future measurement of the experimental sites at ages five, 10 and 15 years will provide longer term data on the effects of various stocking rates and thinning regimes and facilitate modification and improvement of these silvicultural prescriptions.
The Impacts of Plantations and Native Forests on Water Security: Review and Scientific Assessment of Regional Issues and Research Needs. PRC071-0708	Polglase P and Benyon R (2009). The Impacts of Plantations and Native Forests on Water Security: Review and Scientific Assessment of Regional Issues and Research Needs	The impacts of plantations on water security have probably been over emphasised when considered at regional and national scale. This is especially so when considered at whole-of-catchment scale, the amount of water intercepted by plantations compared with downstream users and other components of the water balance. Local scale impacts are important in some areas especially where plantations occupy a large proportion of a unit of water management. For several jurisdictions, groundwater issues emerge as the primary concern, despite the recent national emphasis on the impacts of plantations on surface water supplies. For many of the important catchments suppling drinking water and environmental flows, native forests exert the overwhelming control on water availability. In these areas, greater research effort is needed to understand future water availability from native forests.

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Title/ Project No	FWPA Report/ Date	Findings/ outcomes
The Variable Retention Harvest System. PNC062-0607	Lindenmayer D (2009) Variable retention harvesting in Victorian mountain ash forest	A major experiment examining the efficacy of the Variable Retention Harvesting System (VRHS) has been underway since late 2003. The study is focused on 1939 regrowth Mountain Ash forest in Victoria. The experiment involves comparing biodiversity responses in traditionally logged (clearfelled) sites with coupes where islands of forest cover were retained. The key target response groups being quantified are birds, small terrestrial mammals and plants. These groups are surveyed before logging, after logging, after the application of regeneration burning, and then repeatedly once new stands of trees have become established in logged areas. The VRHS experiment entails 24 coupes allocated to four experiment treatments in each of six blocks. The treatments are: **(1)** Traditional clearfell. **(2)** One retained island of 1.5 ha. **(3)** Three retained islands of 0.5 ha each. And, **(4)** No logging (1939 aged pseudo-coupe). The experiment will be fully implemented by late March 2009. After this date the project will enter a phase of long-term monitoring and the longitudinal response of different biotic groups will be quantified over time. A major series of scientific papers will be published from the work, commencing in mid-2009. VRHS is more difficult to implement than traditional clearfelling. However, the work to date has indicated that it is logistically feasible to implement VRHS in logged Mountain Ash forests. In particular, islands of 1.5 ha are more straight-forward to establish and maintain than multiple ones of 0.5 ha, especially during the regeneration burning phase of coupe preparation. It appears most appropriate to implement VRHS on flatter parts of the landscape where islands are more straight-forward to protect from regeneration burning. Earlier work suggests that an appropriate target for the implementation of VRHS would be ~30% of coupes. There are substantial reductions in populations of small mammals and birds on logged sites immediately following harvesting of the area immediately adjacent to retained islands. However, small numbers of individuals of several species of birds as well as small mammals persist permanently in the islands, not only directly after logging but also following the regeneration burn and the development of regenerated stands in the surrounding harvested area. Distinct changes in the bird assemblage have been observed within 2-3 years of the development of regenerated stands in the area surrounding the retained islands. These initial findings tentatively suggest that patterns of species richness may recover relatively quickly to pre-logging levels. Some components of the vegetation cover and plant species composition of the retained islands have undergone some deterioration following harvesting in the surrounding coupe. The extent of deterioration appears to be linked with the amount of scorch of the regeneration burn. The experiment has involved close collaboration between ANU researchers, DSE staff and logging contractors. The work provides a rare but nevertheless important example of true active adaptive management. A key aim will be to continue long-term monitoring of all 24 coupes in the experiment for at least a 10-20 year period beyond March 2009.

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Appendix 3. Papers published in Australian Forestry, with relevance to native forest silviculture and management, from 2009-2018

1. Abbott I and Williams MR (2011). Silvicultural impacts in jarrah forest of Western Australia: synthesis, evaluation, and policy implications of the Forestcheck monitoring project of 2001–2006. *Australian Forestry*,74:4, 350-360.

2. Abbott I, Liddelow GL, Vellios CV, Mellican AE and Williams MR (2011). Forestcheck: the response of birds to silviculture in jarrah (*Eucalyptus marginata*) forest. *Australian Forestry*, 74:4, 328-335.

3. Baker SC and Read SM (2011). Variable retention silviculture in Tasmania's wet forests: ecological rationale, adaptive management and synthesis of biodiversity benefits. *Australian Forestry*, 74:3, 218-232.

4. Bar-Ness YD, Kirkpatrick JB and McQuillan PB (2012). Crown structure differences and dynamics in 100-year-old and old-growth *Eucalyptus obliqua* trees. *Australian Forestry*, 75:2, 120-129.

5. Barr R, Wright W and Rayment P (2011). Thinning, fire and birds in Boola Boola State Forest, Victoria, Australia. *Australian Forestry*, 74:1, 43-53.

6. Booth TH (2017). Impacts of climate change on eucalypt distributions in Australia: an examination of a recent study. *Australian Forestry*, 80:4, 208-215.

7. Booth TH, Raison RJ, Crawford DF, Jovanovic T, O'Connor MH, Raisbeck-Brown N, O'Connell DA, Hogg BW and Lee DJ (2014). Biomass for aviation fuel production in the Fitzroy Basin, Queensland: a preliminary assessment of native and plantation forest potential. *Australian Forestry*, 77:1, 1-8.

8. Brack CL and McLarin M (2017). Strategic forest planning and operational decisions under uncertainty. *Australian Forestry,* 80:2, 69-77.

9. Bren L, Jeyasingham J and Davey S (2013). Impacts of native forest harvesting on flows into the Murray–Darling Basin system. *Australian Forestry*, 76:2, 91-100.

10. Cargill J, Van Etten E, Whitford K, McCaw L and Stock W (2016). A refined method for estimating capsule crops in individual jarrah (*Eucalyptus marginata*) crowns. *Australian Forestry*, 79:3, 208-216.

11. Collett NG and Fagg PC (2010). Insect defoliation of mixed-species eucalypts in East Gippsland. *Australian Forestry*, 73:2, 81-90.

12. Comerford E, Norman PL and Le Grand J (2015). Is carbon forestry viable? A case study from Queensland, Australia. *Australian Forestry*, 78:3, 169-179.

13. Cookson LJ and McCarthy KJ (2013). Influence of tree age and density on the above-ground natural durability of eucalypt species at Innisfail. *Australian Forestry*, 76:3-4, 113-120.

14. Cranfield RJ, Robinson RM, Williams MR and Tunsell VL (2011) Forestcheck: the response of lichens and bryophytes to silviculture in jarrah (*Eucalyptus marginata*) forest. *Australian Forestry*,74:4, 303-314.

15. Cruz MG, Gould JS, Alexander ME, Sullivan AL, McCaw WL and Matthews S (2015). Empirical-based models for predicting head-fire rate of spread in Australian fuel types. *Australian Forestry*, 78:3, 118-158.

16. Cummins J, Skennar C, Capill L, Cassidy M and Palmer G (2016). Using small hardwood logs to produce liquid fuels and electricity, *Australian Forestry,* 79:3, 189-195.

17. Davey SM (2018). Regional forest agreements: origins, development and contributions. *Australian Forestry*, 81:2, 64-88.

18. Doley D (2010). The response of forests to climate change: the role of silviculture in conserving threatened species. *Australian Forestry*, 73:2, 115-125.

19. Dooley GM, Murray MD, Lutze MT, McCarthy GJ, Perry PC and Fagg PC (2010). Seedcrop development in *Eucalyptus viminalis* in High-Elevation Mixed Species forest of East Gippsland. *Australian Forestry*, 73:1, 24-33.

20. Erskine WD (2009). Natural versus anthropogenic sources of channel sand and fine gravel following integrated logging in the Letts Creek catchment, NSW. *Australian Forestry*, 72:2, 61-70.

21. Evans B, Stone C and Barber P (2013) Linking a decade of forest decline in the south-west of Western Australia to bioclimatic change. *Australian Forestry*, 76:3-4, 164-172.

22. Fagg P, Lutze M, Slijkerman C, Ryan M and Bassett O (2013). Silvicultural recovery in ash forests following three recent large bushfires in Victoria. *Australian Forestry*, 76:3-4, 140-155.

23. Farr JD, Wills AJ, Van Heurck PF, Mellican AE and Williams MR (2011). Forestcheck: the response of macro-invertebrates to silviculture in jarrah (*Eucalyptus marginata*) forest. *Australian Forestry*,74:4, 315-327.

24. Ferguson I (2011). Strategic seedbanks to meet fire risks for Victorian ash-type species. *Australian Forestry,*74:2, 97-107.

25. Ford RM (2013). Contested social values in decision-making for Australian native forests. *Australian Forestry*, 76:1, 37-49.

26. Ford RM, Williams KJH, Bishop ID and Hickey JE (2009). Public judgements of the social acceptability of silvicultural alternatives in Tasmanian wet eucalypt forests. *Australian Forestry*, 72:4, 157-171.

27. Fox JC, Hamilton F and Occhipinti S (2009). Tree hollow incidence in Victorian state forests. *Australian Forestry*, 72:1, 39-48.

28. Grigg AH and Grant CD (2009). Overstorey growth response to thinning, burning and fertiliser in 10–13-year-old rehabilitated jarrah (*Eucalyptus marginata*) forest after bauxite mining in south-western Australia. *Australian Forestry*, 72:2, 80-86.

29. Haywood A and Stone C (2011). Semi-automating the stand delineation process in mapping natural eucalypt forests. *Australian Forestry*, 74:1, 13-22.

30. Haywood A and Stone C (2011). Using airborne laser scanning data to estimate structural attributes of natural eucalypt regrowth forests. *Australian Forestry*, 74:1, 4-12.

31. Hickey J, Neyland M, Rothe A and and Bauhus J (2015). Is continuous-cover silviculture, as practised in Bavaria, suitable for use in wet eucalypt forests in Tasmania, Australia? *Australian Forestry,*78:1, 29-44.

32. Jay VA and Dillon A (2016). Modelling the outcomes of different silvicultural approaches in the private native forests of north-eastern New South Wales, Australian Forestry, 79:2, 85-95.

33. Kantvilas G, Jarman SJ and Minchin PR (2015). Early impacts of disturbance on lichens, mosses and liverworts in Tasmania's wet eucalypt production forests. *Australian Forestry*, 78:2, 92-107.

34. Keenan RJ (2017). Climate change and Australian production forests: impacts and adaptation. *Australian Forestry*, 80:4, 197-207.

35. Keenan RJ and Nitschke C (2016). Forest management options for adaptation to climate change: a case study of tall, wet eucalypt forests in Victoria's Central Highlands region. *Australian Forestry*, 79:2, 96-107.

36. Kinny M, McElhinny C and Smith G (2012). The effect of gap size on growth and species composition of 15-year-old regrowth in mixed blackbutt forests. *Australian Forestry*, 75:1, 3-15.

37. McCaw WL (2011). Characteristics of jarrah (*Eucalyptus marginata*) forest at FORESTCHECK monitoring sites in south-west Western Australia: stand structure, litter, woody debris, soil and foliar nutrients. *Australian Forestry*, 74:4, 254-265.

38. McCaw WL, Robinson RM and Williams MR (2011). Integrated biodiversity monitoring for the jarrah (*Eucalyptus marginata*) forest in south-west Western Australia: the FORESTCHECK project. *Australian Forestry,* 74:4, 240-253.

39. Moroni MT (2013). Simple models of the role of forests and wood products in greenhouse gas mitigation. *Australian Forestry*, 76:1, 50-57.

40. Moroni MT and Musk RA (2014). Domestic timber harvesting affects wood quantities in Tasmanian dry eucalypt forests. *Australian Forestry*,77:2, 86-91.

41. Neyland M, Hickey J and Read SM (2012). A synthesis of outcomes from the Warra Silvicultural Systems Trial, Tasmania: safety, timber production, economics, biodiversity, silviculture and social acceptability. *Australian Forestry*, 75:3, 147-162.

42. Ngugi MR, Doley D, Botkin DB, Cant M, Neldner VJ and Kelley J (2014). Long-term estimates of live above-ground tree carbon stocks and net change in managed uneven-aged mixed species forests of sub-tropical Queensland, Australia. *Australian Forestry*, 77:3-4.

43. Norris J, Arnold S and Fairman T (2010). An indicative estimate of carbon stocks on Victoria's publicly managed land using the FullCAM carbon accounting model. *Australian Forestry*, 73:4, 209-219.

44. Platen JV, Kirkpatrick JB and Allen KJ (2011). Fire frequency variation in south-eastern Tasmanian dry eucalypt forest 1740–2004 from fire scars. *Australian Forestry*, 74:3, 180-189.

45. Powell CJ and Sedunary DN (2013). Development of a threatened fauna management framework across Victoria's state forests. *Australian Forestry*, 76:1, 10-15.

46. Poynter M and Ryan M (2018). Leadbeater's possum and Victoria's Central Highlands' forests: flawed science and environmental activism as drivers of forest management change. *Australian Forestry*, 81:4, 250-272.

47. Pratley JE, Kanowski PJ and Bull LM (2010). Education and training challenges for the Australian forestry sector: an analysis based on recent trends in university and vocational education and training (VET) completions. *Australian Forestry*, 73:4, 227-233.

48. Proctor E and McCarthy G (2015). Changes in fuel hazard following thinning operations in mixed-species forests in East Gippsland, Victoria. *Australian Forestry*, 78:4, 195-206.
49. Jurskis V (2016). Dieback' (chronic decline) of *Eucalyptus viminalis* on the Monaro is not new, unique or difficult to explain. *Australian Forestry*, 79:4, 261-264.

50. Robinson RM and Williams MR (2011). Forestcheck: the response of epigeous macrofungi to silviculture in jarrah (*Eucalyptus marginata*) forest. *Australian Forestry*, 74:4, 288-302.

51. Ross C and Brack C (2015). *Eucalyptus viminalis* dieback in the Monaro region, NSW. *Australian Forestry*, 78:4, 243-253.

52. Ryan M (2013). Adaptive silviculture in regrowth eucalypt forests in Victoria and the implications for water, wood, wildlife and wildfire, Australian Forestry, 76:3-4, 173-182.

53. Scott RE, Neyland MG and Hovenden MJ (2015). Variable-retention harvesting in Tasmania: regeneration success? *Australian Forestry*, 78:4, 232-242.

54. StClair P (2010). Rehabilitation of declining stands at Mt Lindesay: a preliminary assessment. *Australian Forestry*, 73:3, 156-164.

55. Stone H and Wood D (2010). Sustainable pole supply project. *Australian Forestry*, 73:4, 220-226.

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61. Whitford KR, Stoneman G, Seymour A, Murray P, Eaton L and Tanimoto M (2012). The effects of cording, timber load and soil gravel content on soil compaction during timber harvesting on moist soils. *Australian Forestry*, 75:2, 107-119.

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Appendix 4. Modelled productivity increases from thinning of ash-type forest

LaSala *et al* (2004) compared, among other scenarios, the yields from thinned and unthinned *E. obliqua* forest in Tasmania based on modelled yields over an 80-year rotation from coupes on highly productive sites. The thinning was modelled to occur at 32 years and retain 250 stems per ha.

The yield comparisons are summarised below:

	Thinned		**Unthinned**	
	m^3/ha	m^3/ha/y	m^3/ha	m^3/ha/y
Pulplog from thinning	152	4.9	0	-
Pulplog from final harvest	364	4.6	553	6.9
Pulplog total	516	6.5	553	6.9
Sawlog from final harvest	384	4.8	275	3.4
Total	900	11.3	828	10.4

Appendix 5. Project justifications and prospective benefits to be derived from projects recommended for implementation in 2019/20 to 2023/24.

1. Commercial thinning guided by remote sensing.

Although commercial thinning has been identified as a desirable silvicultural practice for many eucalypt forest types its implementation has been limited by high planning, harvesting, supervision and compliance costs. Thinning guidelines have often targeted potential thinning areas based on age criteria and on broad density stem classes derived from aerial interpretation of film-based photography (eg. Forestry Tasmania 2001). Prospective areas in Tasmania were then proven up by establishment of ground-based plots (0.01 ha) at a rate of one per ha, which provided an average estimate of density that provided little indication of the variation in actual stem density in the site. Post-thinning outcomes were determined by establishing similar plots to check if targeted retention, and minimum damage, specifications had been achieved.

This approach was cumbersome and expensive and sometimes failed to target thinning on the areas that most needed it, while treating other areas that would have been best avoided if accurate knowledge had been available on terrain and stand conditions.

Many native forest growers have access to recent LiDAR data that provide highly accurate information on terrain conditions and potentially tree density. UAVs and digital aerial photography offer cost effective means of capturing imagery to determine post thinning outcomes.

The project should have three phases:

1. Evaluate the range of remote sensing technologies for selecting patches of forest to thin within heterogenous native forests.
2. Seek to identify individual stems for retention, eg the tallest 200 stems/ha in an identified zone, so that GPS co-ordinates can be uploaded to harvester units.
3. Improve the accuracy and efficiency of post-thinning records of retained stems as a feedback mechanism to harvesters, and as an input to yield forecasting.

While this use of remote sensing would be novel in native forest thinning, it is being developed for plantations in Australia (Caccamo et al 2018) and Canada (Lamb et al 2018).

Anticipated Gains:

Cheaper thinning programs should allow increased thinning, which would increase sustainable sawlog yield.

Potential Proponents for Project Development:

- FCNSW
- FPC
- STT
- Midway
- Vicforests
- ANU
- DPI, NSW
- UTAS

References:

Caccamo G, Iqbal IA, Osborn J, Bi H, Arkley K, Melville G, Aurik D and Stone C (2018). Comparing yield estimates derived from LiDAR and aerial photogrammetric point-cloud data with cut-to-length harvester data in a *Pinus radiata* plantation in Tasmania, *Australian Forestry,* 81: 131-141.

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Lamb SM, MacLean DA, Hennigar CR, Pitt, DG (2018). Forecasting Forest Inventory Using Imputed Tree Lists for LiDAR Grid Cells and a Tree-List Growth Model. *Forests* 9, 167.

2. Remote sensing regeneration success

Regeneration surveys are routinely done manually after regeneration harvests in Victoria, Tasmania and Western Australia to provide reliable data on regeneration success and inform needs for remedial treatments or revised silviculture. These surveys incur significant costs and could potentially be undertaken remotely by unmanned aerial vehicles (UAVs), digital imagery and purpose-built software applications.

This project seeks to explore the use of LiDAR and Digital Aerial Photography, and UAV and microsatellite technology to determine regeneration success. It may be well suited to a PhD candidate with strong support from forest growers. It will be important to capture and analyse remote sensing over a range of seasonal conditions and topographies in order to reliably distinguish eucalypts from other colonising vegetation.

Anticipated Gains:

Cost reductions and reduce risks to field staff in undertaking surveys in difficult terrain.

Potential Proponents for Project Development:

- FPC
- STT
- Vicforests
- ANU
- UTAS

References:

Bassett O, Fagg P, Slijkerman C, Lutze M (2015). Eucalypt stocking surveys and regeneration monitoring. Native forest silviculture guideline; no. 10. Department of Economic Development, Jobs, Transport and Resources.

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3. Integrated harvesting of high-graded private native forests southern Queensland and northern NSW

Current FWPA funded work (Lewis et al. in prep.) in sub-tropical private native forest (southern Queensland and northern NSW) has recognised the potential of silvicultural treatments to improve productivity. This study investigated a number of different non-commercial silvicultural treatment options (e.g. thinning to waste across different stand densities, with different treatment techniques, most commonly applied with stem injection). On average, silviculturally treated areas had tree DBH growth increments that were approximately four times those on trees in areas that had not been treated. As this growth is concentrated on merchantable trees in treated stands, merchantable volume growth increments on individual trees were also significantly greater in these stands. At a stand-level in dry eucalypt forests, average merchantable volume growth is almost doubled in treated stands (i.e. 0.76 m^3/ha/year in untreated, but previously harvested forest and 1.45 m^3/ha/year in treated forest). Further, actively managing the native forests on a property has the potential to return multiple benefits to the landholder, particularly in the form of a dual income stream from livestock grazing and timber production. There is great potential to improve the hardwood timber production from private native forests, given their large extent (i.e. over 2 million ha of forest mapped as potentially harvestable in southern Queensland and 3.4 million ha on the north coast of NSW) and current poor productive condition (Jay 2017; Cameron et al 2019, Lewis et al in prep). Based on recent sawmill surveys in southern Queensland, the private native forest resource contributes approximately 208 900 m^3 of hardwood sawlog and an additional 18 100 m^3 of pole products. On the north coast of NSW harvesting contractors estimated that approximately 274 950 m^3 of private native forest logs are sold each year (Jamax Forest Solutions 2018). Potential future sustainable annual yields from private native forests in southern Queensland were estimated at between 150 000 m^3/y and 600 000 m^3/y, depending on level of landholder participation in timber production (estimated between 30% and 50% of the mapped commercially productive private native forest) and application of silvicultural treatments within their forests (simulated to range between 0% and 50%). As an example, if 40% of private native forests were managed for timber production and 30% of these were silviculturally treated, private native forests are predicted to be able to sustainably supply 368 000 m^3/y. That is 10% more log volume than crown and private forests in Queensland combined are supplying to the industry at present. Encouraging silvicultural management of private native forests will lead to many flow-on benefits, including greater outputs from regional sawmills and employment opportunities.

The net present value (NPV) of perpetual native forest management with and without silvicultural treatment was estimated for six commercially important forest types in Queensland. At a discount rate of 5%, silvicultural treatments were financially viable (NPV > $0) and exceeded returns from harvesting without silvicultural treatment for most forest types (Lewis et al. in prep). Despite this there are significant constraints that prevent individual forest managers (e.g. landholders) from investing in forest management. Key constraints include: (1) sovereign risk (concerns regarding regulatory requirements, particularly the uncertainty around the impact of future legislation on an ability to harvest the forest); (2) the up-front costs associated with silvicultural treatment and the associated long pay-back periods; (3) private landholders are generally not well informed about how to manage their forests for timber production and are not familiar with timber markets; and (4) a lack of markets for residues and small-diameter thinning material.

This new project will concentrate on helping break-down constraints to investment in forest management through considering additional products or markets that could help make silvicultural treatments more attractive to forest managers. Extraction of biomass for bioenergy markets represents a potential opportunity to help cover the immediate costs of silvicultural treatments thereby enabling more sustainable practices. There is also potential to utilise small-diameter logs through rotary peeling (e.g. McGavin and Leggate 2019) that could help make silvicultural treatments more attractive to forest

managers. Such activities would typically take place at the time of an initial harvest, and in some cases a reset harvest (within the limits of relevant Codes) might be necessary in highly degraded forests. However, there is a need to determine whether additional harvesting (e.g. for biomass or small-diameter log products) or removal of biomass from a site (e.g. removal of tree heads for biomass) can be accomplished (and at what appropriate level) without having a negative impact on the site resources that are needed to maintain future site productivity and healthy stand dynamics. The impacts of such harvesting activities on the residual stand (e.g. damage to valued sawlogs) and habitat values (e.g. coarse woody debris) need to be quantified. Initially this might involve a review of the potential environmental impacts and their resultant growth or yield implications. There are also questions around how biomass harvesting could be carried out most efficiently, and whether it is a viable business proposition for industry. While there is interest from private land owners and commercial entities alike the enabling systems and financial considerations along with environmental ramifications of these emerging uses need to be analysed. This would provide more confidence for investment in developing residue markets.

Further investment is also needed to better inform private landholders on the value of forest management. This would involve working with extension groups, such as the Private Forestry Service Queensland. Landholder-friendly manuals and training videos and workshops could form part of a suite of presentation materials to ensure uptake of best practice silvicultural management.

Anticipated Gains:

The metrics to measure likely gains need to be determined but could include:

- The area (x ha) treated for productivity improvements (eg. by integrated harvesting and, or non-commercial treatments) over five years.
- The productivity improvement after five years = x ha by (1.45-0.76) cubic metres per year.
- The stumpage value of the productivity improvement.

Potential Proponents for Project Development:

- QDAF
- PFSQ
- FPC
- SCU

References:

Cameron NL, Lewis T and Ryan S (2019). Drawing meaning and direction from private native forest research – a summation of two recent studies. *Australian Forestry*. DOI: 10.1080/00049158.2019.1595348.

Jamax Forest Solutions (2018). Report on survey of NSW north coast private native forest harvesting contractors. Available from: https://www.dpi.nsw.gov.au/forestry/private-native-forestry

Jay A. (2017). Condition of NSW North Coast Private Forest. Report to NSW Department of Primary Industries.

Lewis T, Venn T, Francis B, Ryan S, Brawner J, Cameron N, Kelly A, Menzies T and Catchpoole K. (in preparation). Improving productivity of the sub-tropical private native forest resource. Report prepared for Forest and Wood Products Australia (PNC379-1516).

McGavin RL and Leggate W (2019). Comparison of processing methods for small-diameter logs: Sawing versus rotary peeling. *BioResources* 14(1): 1545-1563.

4. Options for improving jarrah forest productivity

This project would quantify the area affected by overstocking; the current rate of stand growth; the productivity improvement if stands could be treated so they have optimum stockings; and, identify options for applying those treatments. One of the options to be explored is for the stands to be commercially thinned if markets can be identified.

The mid-term review of WA's Forest Management Plan 2014-2023 identified that the forest health and productive capacity objectives for jarrah forests were not being fully met because of the excessive retention of unmarked trees, which in turn was due to insufficient access to markets for jarrah and marri other bole volume (Parks and Conservation Commission 2018). The Forest Products Commission seeks to better utilise the available material through expanding access to markets for other bole volume, the application of new technologies and processes to reduce production costs and undertake trials of suitability for various engineered wood products. At this stage the areas of low productivity and the potential for improvement have not been reported. This issue is somewhat similar to dry forests on private land in Queensland where current increments of less than 1 m^3/ha/y are likely to be doubled if markets for other bole volume can be developed.

Anticipated Gains

The metrics to measure likely gains need to be determined but could include:

The area (x ha) treated for productivity improvements (eg. by thinning or non-commercial treatments over five years).

The productivity improvement after five years = x ha by (y-z) cubic metres per year.

The value of the productivity improvement to retained trees.

reated stands should increase water availability and ecosystem resilience.

Potential Proponents for project development:

- FPC
- DCBA
- Midway

References:

Parks and Conservation Commission (2018). Draft mid-term review of performance of the Forest Management Plan 2014-2023. Draft for public comment. September 2018. Government of Western Australia

5. Evaluation of previous productivity research investments

Most public native forest growers have inherited a legacy of past research investments in productivity, particularly thinning trials. This project would aim to identify a subset of well-designed trials that have not been fully analysed, may be worthy of further measurement and should be reported. The project would have three components:

- Identification of candidate trials for analysis and reporting
- Remeasurement of trials where warranted
- Analysis of key trials and submission of papers to journals

Trials that have high potential to be considered are thinning trials described by Connell et al (2004) and La Sala (2006, 2007).

Other long-term trials (especially of thinning) may also merit final measurements and publication to better inform current or potential thinning programs.

Anticipated Gains

Knowledge to inform current or potential thinning programs

Potential Proponents for project development

- FCNSW
- STT
- ANU
- DBCA
- UTAS
- SCU
- UniMelb

References:

Connell MJ, Raison RJ and Jenkins P (2004). Effect of thinning and coppice control on stand productivity and structure in a Silvertop Ash (*Eucalyptus sieberi* L. Johnson) forest. *Australian Forestry* 67: 30-38.

La Sala AV (2006). Pre-commercial thinning and fertiliser enhance growth in young native *Eucalyptus obliqua* (L'herit) stands in Tasmania. *Australian Forestry* 69: 16-24.

La Sala AV (2007). Long-term response of *Eucalyptus regnans* F.Muell. to commercial thinning in a regrowth eucalypt forest in Tasmania. *Australian Forestry* 70: 167-172.

6. Understanding needs of private native forest growers

Australia's *State of the forest report 2018* indicated knowledge of private native forest owners' aspirations as a key gap in predicting wood flows from the private native forest estate. Because the supply of high-quality logs from public multiple-use native forests is predicted to decline, the importance of private native forests for the supply of hardwood logs is predicted to increase.

- There is insufficient information to assess the sustainability of current or predicted future rates of wood harvest from private native forests. These limitations on information continue to remain an impediment regionally and nationally for regional forest industry planning (Burns et al. 2015).
- Objectives for private native forests are different to State native forest growers (Dare and Eversole 2013). Their attitudes and aspirations are important to maintaining significant supply of forest products from the private forest estate.

This project would seek to determine the values, aspirations and silvicultural preferences of private native forest growers? The focus of the project would be private native forest owners in Queensland, New South Wales and Tasmania, which are the main sources of timber from the private native forest estate.

Anticipated Gains

Increased knowledge for private native forest support agencies to provide assistance to encourage sustainable forest management.

Potential proponents for project development

- QDAF
- Local Land Services, NSW
- Private Forests Tasmania
- QDAF
- SCU

References

Dare M and Eversole R (2013). Forest owner intent: Harvesting Tasmania's non-industrial private forests – The intent of Tasmania's private forest growers to harvest their forest estate. Report prepared for Private Forests Tasmania, Institute for Regional Development, Private Forests Tasmania, Hobart.

Burns K, Gupta M, Davey S, Frakes I, Gavran M and Hug B (2015). Outlook scenarios for Australia's forestry sector: key drivers and opportunities. ABARES report to client prepared for the Department of Agriculture, ABARES, Canberra.

7. Climate-adapted protocols for provenances and species

The effect of rising temperature is expected to cause species range shifts that are most likely to be southerly or to higher elevations. Native forest communities are likely to experience local extinctions, introduction of new species, and higher potential for diseases, weeds and pests that are likely to result in changes to forest structure and disruption of biotic processes. There is also likely to be an increase in wildfire frequency that will increase tree mortality and, in young regenerating stands, jeopardise forest re-establishment.

Native forest growers use seed-zone systems to prescribe the use of on-site or in-zone seed for regeneration. However, climate change may well dictate that alternative provenances, and perhaps even alternative native forest species, are better matched to future site conditions.

This project would develop measures to improve provenance decision-making, including embedding provenance trials, developing dynamic, evidence-based provenance policies; and establishing stronger research–grower collaborations to facilitate the adoption of research outcomes.

A suite of well-targeted provenance and species trials, guided by modelling of past and future regional climates, could be established to inform this question and lead to more adaptive seed zone prescriptions.

This is most relevant to managing provenance selection for growers who apply broadcast sowing but is also relevant to growers who use supplementary planting as part of their regeneration treatments.

Anticipated gains:

Climate-adapted seed provenance protocols

Potential proponents for project development

- STT
- Vicforests
- DELWP
- UniMelb
- UTAS

References:

Breed MF, Harrison PA, Bischoff A, Durruty P, Gellie NJC, Gonzales EK, Havens K, Karmann M, Kilkenny FF, Krauss SL, Lowe AJ, Marques P, Nevill PG, Vitt PL and Bucharova A (2018). Priority actions to improve provenance decision-making. *BioScience* 68: 510-516.

Keenan RJ (2017). Climate change and Australian production forests: impacts and adaptation. *Australian Forestry* 80: 197-207.

Keenan RJ and Nitschke C (2016). Forest management options for adaptation to climate change: a case study of tall, wet eucalypt forests in Victoria's Central Highlands region. *Australian Forestry* 79: 96-107.

8. Decision support apps for harvest planning

This project would develop mobile apps to assist forest planning and reduce the cost of preparing timber harvesting plans.

Preparation of timber harvesting plans is time consuming and expensive. In 2017/18 over 100 timber harvesting (Forest Practices) plans were prepared for native forest harvesting in Tasmania. This suggest that nationally over 500 such plans might be prepared annually.

The mobile app, or apps, would access existing environmental, productivity and regulatory data sets in order to assist forest planning (especially for private growers). This could include:

- Landsat imagery, NCAS (National Carbon Accounting System) productivity estimates and disturbance history.
- Habitat and regulatory requirements/management constraints.
- Inventory system and management advice.

Potential Proponents for Project Development:

- PFT
- PFSQ
- LLS, NSW
- ANU

9. Guidelines for responsible recovery of timber from burnt forests

Bushfires have always been part of the forested landscape and may be increasing due to climate change. When areas designated for wood production are burnt, efforts are usually made to recover the fire-damaged timber. The science literature by ecologists and hydrologists highlights the negative aspects of salvage logging, often without acknowledging the benefits.

- Negative impacts of the salvage harvesting can be reduced with responsible harvesting, including the retention of islands of less burnt forest.
- The suitability of fire-damaged wood for particular uses (sawn, engineered wood products, pulp) needs to be better understood by growers and customers. A range of often-conflicting views on suitability are advanced by customers. While much has been learnt about timber properties and markets, very little of that knowledge has been made available to guide future salvage harvesting operations.
- This project would engage a consultant, or consultants, to review all relevant literature and document what growers know, and what they need to know, about responsible salvage harvesting drawing on experiences from Victoria (2003, 2006, 2009 bushfires), WA (2015 and 2016 bushfires) and Tasmania (2016 and 2019 bushfires) and with particular reference to: OHS, habitat retention, water quality, market (wood quality and timing) and assisted regeneration requirements. The work should also consider regulatory and certification requirements.
- The documentation could include clear guidance on responsible approaches to salvage harvesting to minimise negative effects for biodiversity and productivity of the future forest. The guidelines should also inform the timing and nature of salvage harvesting to optimise value in timber markets.

Anticipated gains:

Guidelines for responsible recovery of timber from burnt forests

Optimising salvage of burnt timber to markets

Potential proponents for project development

- Vicforests
- DEWLP
- FPC
- DCBA
- STT
- Midway
- UTAS
- UniMelb

References

Fagg P, Lutze M, Slijkerman C, Ryan M and Bassett O (2013). Silvicultural recovery in ash forests following three recent large bushfires in Victoria. *Australian Forestry* 76: 140-155.

Lindenmayer DB, Banks SC, McBurney L, Blair D, Wood J (2017). From unburnt to salvage logged: Quantifying bird responses to different levels of disturbance severity. *Journal of Applied Ecology* (online).

10. Coarse Wood Debris prescriptions for high residue removals

Coarse woody debris (CWD) is the standing and fallen dead wood in a forest and serves an important role in ecosystem functioning, especially as habitat for invertebrate fauna.

- Studies in Tasmania, partly stimulated by potential biomass energy projects, indicated that CWD levels in wet eucalypt forests are very high. While draft prescriptions for retention were developed they have yet to be required because CWD levels thus far have exceeded likely minimum thresholds.
- Less is known about CWD levels and dynamics in dry forests. This project is a high priority for WA jarrah where prescribed burning may interact over time to deplete CWD retained at harvest events.
- This project also has relevance to any native forests where a high level of residue removal is planned or undertaken.
- This project would review data of CWD levels in harvested and unharvested forests for major commercial native forest types; establish additional plots where information is lacking; develop simple models to indicate CWD levels over time; and develop prescriptions for CWD retention where minimum retention levels would not otherwise be assured.

Anticipated gains:

- Practical prescriptions for CWD retention after harvesting where minimum retention levels would not otherwise be assured.
- Increased sustainability credentials.

Potential proponents for project development

- FPC
- Vicforests
- UTAS
- QDAF

References

Rothe A, Moroni M, Neyland M, Wilnhammer M (2015). Current and potential use of forest biomass for energy in Tasmania. *Biomass and Bioenergy* 80: 162-172

Grove SJ, Stamm L and Barry C (2009) Log decomposition rates in Tasmanian *Eucalyptus obliqua* determined using an indirect chronosequence approach. *Forest Ecology and Management* 258, 389-397.

McCaw WL (2011) Characteristics of jarrah (*Eucalyptus marginata*) forest at FORESTCHECK monitoring sites in south-west Western Australia: stand structure, litter, woody debris, soil and foliar nutrients. *Australian Forestry*, 74: 254-265.

Woldendorp G and Keenan R (2005) Coarse Woody Debris in Australian Forest Ecosystems: A Review. *Austral Ecology* 30(8), 834-843.

11. National workshop on long-term monitoring

Growers need to know how resilient their forests will be to harvesting, wildfires, disease and climate change, which requires long-term monitoring. They also need effectiveness monitoring to determine if their management actions are working (as per regulatory and certification requirements), and particularly for threatened species.

- Many agencies have an interest in long-term monitoring, but few are prepared to fund it (at least not without partners). Australia's Terrestrial Ecological Research Network (TERN) is the lead agency for fostering long-term research sites but needs contributors.
- Growers could play a useful role by asking FWPA to facilitate and co-fund a national workshop to determine "What long-term monitoring worked, and what didn't? How should we best go forward, given likely budgets and resources?"
- The workshop should particularly consider monitoring outcomes and futures for the FORESTCHECK, Warra LTER and Victorian Silvicultural Systems projects.
- The key need is for a funded co-ordinator to: develop a workshop program, informed by a voluntary committee; attract sponsors and partners; and, engage a conference organiser to organise the logistics with costs paid by attendees (and offset by site partners and sponsors). Workshop presentations could be lodged on a website and a short synthesis of proceedings and recommendations should be prepared for FWPA and potential long-term site partners.
- Some funds might be used to sponsor key speakers or to allow long-term data sets to be analysed for presentation at the workshop.

Anticipated gains:

- Increased awareness of, and commitment to, significant long-term monitoring efforts.
- Identification of cost-effective monitoring approaches to meet regulatory and certification requirements.

Potential proponents for project development

- UTAS, and leader of the Warra LTER site
- FPC
- DELWP
- UniMelb
- UniMelb
- Southern Cross University

References

Brown MJ, Elliott HJ and Hickey JE (2001). An overview of the Warra Long-Term Ecological Research Site. *Tasforests,* 13(1): 1-8.

Burns E and Lindenmayer D (2014). *Policy handbook: learning from long-term research to better manage biodiversity in Australia*. CSIRO publishing, Collingwood, Melbourne.

EPA (New South Wales Environment Protection Authority) (2013a). *The Private Native Forestry Code Outcomes Monitoring Project.* A report prepared by Paul Killey, NSW Environment Protection Authority, Sydney.

FPA (Forest Practice Authority) (2018). *Monitoring the effectiveness of the biodiversity provisions of the Tasmanian Forest Practices Code*. FPA, Hobart.

McCaw WL, Robinson RM and Williams, MR (2011). Integrated biodiversity monitoring for the jarrah (*Eucalyptus marginata*) forest in south-west Western Australia: the FORESTCHECK project, *Australian Forestry*, 74:4, 240-253.

Squire RO (1987). Revised treatments, design and implementation strategy for the Silvicultural Systems Project. Department of Conservation, Forests and Lands, Victoria, Lands and Forests. Division. 27 pp. plus Appendices.

12. Reduced reliance on clearfelling and high intensity burning

Of the area of multiple-use public native forest harvested over the period 2011–12 to 2015–16, 86% was harvested by using selection systems, 9% by clearfelling systems, 5% by shelterwood systems, and 0.2% by variable retention systems. The annual average area harvested by clearfelling systems (clearfelling, fire-salvage clearfelling and intensive silviculture with retention) decreased from 17 thousand hectares in 2001–02 to 2005–06 (13% of the total area harvested), to 12 thousand hectares in 2006–07 to 2011–12 (12% of the total area harvested), to 7 thousand hectares in 2011–12 to 2015–16 (9% of the total area harvested) (MPIGA and NFISC 2018).

Clearfelling with high intensity burning is now mainly confined to commercial wet eucalypt forests in Tasmania and Victoria with dense understoreys. Despite the significant reduction in clearfelling, and the inclusion of significant retention at the landscape level, the practice is still somewhat controversial, at least from a social acceptability perspective. The smoke nuisance posed by high intensity burns, and concentrated in a narrow burning window in Autumn, is a significant social acceptance issue.

Variable retention (VR) silviculture is a system developed as an alternative to clearfelling, and with the explicit goal of maintaining species, habitats and structural features at the stand level. About 200 ha per year of variable retention are currently applied annually, mainly in Tasmania (MPIGA and NFISC 2018). The silviculture is now reasonably well developed (Scott et al 2011) but difficult to implement. More widespread adoption of VR is hampered by the difficulty of reducing high slash loads, primarily through burning, while maintaining patches of retained forest within harvest boundaries.

A program of continuing to reduce reliance on clearfelling and high-intensity burning is attractive because it addresses social and biodiversity concerns and may assist growers to meet requirements of forest certification schemes, which seek continuous improvements against social, as well as economic and environmental criteria.

While growers will probably continue to make small reductions in clearfelling over the next five years, a significant shift is unlikely unless practical and cost-effective solutions can be found for reducing the large slash loads that result from the large eucalypt crowns and dense understorey in wet eucalypt forests. Mechanical clearing is one alternative that has so far been demonstrated to be problematic due to high costs and poor soil and seedling growth outcomes.

The most likely “game changer” for moving away from clearfelling and high-intensity burning to more socially acceptable systems (small-patch clearfells, VR or uneven-aged silviculture) would be strong markets for residues. This would allow slash-loads to be considerably reduced and burnt in small heaps under much cooler conditions and over a much longer season.

While this project is fundamentally important, it is recommended that a large research program is not currently needed, at least until stronger markets for residues, or alternative slash-busting technology, are more developed. However, two significant questions can be explored in 2019-2023 with moderate funding, as described below:

A. Understanding the importance of burnt seedbeds for long-term vigour of eucalypts.

Early evaluations of alternatives to clearfelling at the Victorian Silvicultural Systems Trial and at Tasmania’s Warra Silvicultural Systems Trial confirmed the importance of burnt seedbeds for vigorous eucalypt regeneration in wet eucalypt forests. Both these evaluations were made using data up to age three years. There is a need to better understand the importance of burnt seedbeds on long-term

vigour and productivity of eucalypts. Hence about $40k is recommended to stimulate long-term analyses of these trials, or from other relevant trials.

B. Understanding the public's preference for alternative silviculture approaches in forest landscapes.

A small contribution of funds would enable completion of a key paper about the public acceptability of alternative silvicultural approaches in forest landscapes (earlier work by Ford et al 2009 assessed public acceptability at the stand level). The underlying research was titled, *Social Acceptability of Forest Management Options: Landscape Level Visualisation and Evaluation* and was conducted by the University of Melbourne with industry contributions from Forestry Tasmania and the Forest Practices Authority. The researchers guided small groups of forest managers and stakeholders in the development of scenarios representing their visions for forest management. Nine scenarios were then presented to nearly 500 members of the public in a questionnaire for their evaluation. A key finding was that three scenarios were significantly more acceptable than the usual approach to forest management at the time (largely clearfell, burn and sow), while providing similar wood supply. These three scenarios achieved higher natural environment and amenity outputs through different approaches: aggregated retention silviculture; intensification of harvesting in areas of lower conservation value; and creation of a mosaic of forest growth stages suitable for fauna habitat. While elements of this research were published, a key manuscript reporting the scenario findings was not completed due to changing staff roles. A first draft manuscript exists titled, Public Acceptance of Sustainable Forest Management Scenarios in Australia, and framed for an international journal such as Land Use Policy or Forest Policy and Economics.

Anticipated gains:

- Better understanding of public preferences for alternatives.
- Clarification of the importance of burning for eucalypt productivity in the long-term.

Potential proponents for project development

- Vicforests
- STT
- UniMelb
- UTAS

References

Baker SC, Grove, SJ, Wardlaw TJ, McElwee DJ, Neyland, MG, Scott RE, and Read SM (2017). Monitoring the implementation of variable retention silviculture in wet eucalypt forest: A key element of successful adaptive management. *Forest Ecology and Management* 394: 27-41.

Ford R, Williams KJH, Bishop ID and Hickey JE (2009). Public judgements of the social acceptability of silvicultural alternatives in Tasmanian wet eucalypt forests. *Australian Forestry* 72 (4): 157-171.

King M, Hookey P, Baker T and Rab A (1993). The regeneration of *Eucalyptus regnans* under alternative silvicultural systems. 4. Effect of seedbed on seedling establishment. VSP Internal Report 16. Department of Conservation and Natural Resources, Melbourne.

Lindenmayer DB, Blair D, and McBurney L (2019). Variable Retention in Victoria's Mountain Ash (*Eucalyptus regnans*) forests (southeastern Australia). *Ecological Processes* 8: 2.

Neyland M, Hickey J, Beadle C, Bauhus J, Davidson N and Edwards L. (2009). An examination of stocking and early growth in the Warra silvicultural systems trial confirms the importance of a burnt seedbed for vigorous regeneration in *Eucalyptus obliqua* forest. *Forest Ecology and Management* 258: 481-494.

Scott RE, Neyland M and Baker S (2011). Variable Retention Manual. Technical Report 05/2011. Forestry Tasmania, Hobart. 30 pp.

13. Community engagement approaches for native forest growers

A handbook was developed to guide community engagement for plantation managers (Dare M, Schirmer J and Vanclay F. (2010). Handbook for operational community engagement within Australian plantation forest management).

- While some of the social issues are common between native forest and plantation growers many are more prominent with native forestry, eg. around biodiversity, smoke management, use of public native forests.
- This project would review community engagement approaches currently or potentially used for meaningful community engagement by native forest growers, with a focus on increasing social acceptance as well as certification and regulatory requirements.
- It would develop a handbook for operational community engagement for Australian native forest growers.

Anticipated gains:

- Handbook for operational community engagement for Australian native forest growers

Potential proponents for project development

- FPC
- STT
- Vicforests
- Unimelb
- Southern Cross University

Reference

Dare M, Schirmer J and Vanclay F. (2010). Handbook for operational community engagement within Australian plantation forest management. Cooperative Research Centre for Forestry, Hobart, Tasmania, Australia.

14. Future silviculturists: NFS Interest Group and undergraduate support

Native forest growers need a limited number of silviculturists who have practical knowledge and can contribute to, or interpret, scientific literature. There is a declining supply of silviculturists in Australia.

- ANU, Melbourne and Southern Cross universities now have healthy enrolments in forestry related courses which have been rebadged as ecosystem management to downplay the active forestry elements. Students that are interested in silviculture and active management are mostly from overseas countries, eg China and Indonesia, and usually return.
- There are have been so few jobs in native forest silviculture it's hard to convince people to study it, and hard to build degrees around a virtually non-existent job market. But there are now some jobs for silviculturists – we need to call them that.
- A Native Forest Interest Silviculture Group (NFSIG) of grower and research provider representatives is proposed to advise on the implementation of FWPA's Investment Plan for Native Forest Silviculture RDE and to assist with adoption of research products. The NFSIG would have at least one annual teleconference to review progress, conduct a field-based mid-term review of the outputs and success of the research program and advise FWPA on rollout of the second phase of the Investment Plan.
- FWPA could award a $3k annual award for the best honours thesis on native forest silviculture from an Australian university. This would indicate grower support and help identify a cohort of new graduates with an interest and talent for native forest silviculture.

Anticipated gains:

- The Native Forest Silviculture Interest Group would help deploy the research products from this Investment Plan.
- An annual award for the best honours thesis would identify a cohort of new graduates with an interest and talent for native forest silviculture.

Potential proponents for project development

- FCNSW
- FPC
- Vicforests
- STT
- QDAF
- ANU
- Southern Cross University
- UniMelb

15. Standardised silvicultural classification and terminology

- Silvicultural terminology is highly variable across States and jurisdictions and not aligned with international standards. Terms such as Australian Group Selection and seem particularly idiosyncratic.
- Australia's *state of the forests report 2018* indicates that 86% of the annual harvest from public native forests is harvested by using selection systems. However, much of the harvesting included in that category would not be consistent with standard silviculture terminology, which require selection methods to involve: the periodic replacement of single, or small groups (patches) of trees: maintain an all-aged (at least three age classes) stand; and, retain the majority of the basal area at each cutting cycle.
- Aston and Kelty (2018) note that sloppy use of silvicultural terms causes all manner of misunderstanding within the forestry profession and in dealings with the general public.
- The *Ecology and Silviculture of Eucalypts* by Florence (1996) is perhaps the authoritative Australian silvicultural textbook but is somewhat dated, lacks an international perspective (or an index) and is not commonly used for teaching at forestry courses in Australia.
- The main silvicultural texts being used by Australian academics are from North America and include *Forest Stand Dynamics* by Oliver and Larsen (1996), *Forest Ecosystems* by Perry, Oren and Hart (1994) and *The Practice of Silviculture: Applied Forest Ecology* by Ashton and Kelty (2018, previously published as Smith et al 1997). Ideally a modern silviculture textbook for Australia would be written but the task is large and the market is small.
- Patrick Baker is contributing Australian information to the next edition of *Forest Stand Dynamics* (and looking for good examples of stand management).
- *A History of Innovation: Eighty-five Years of Research and Development at Forestry Tasmania* by Elliott, Felton, Jarman and Stone (2008) and *Management of Victoria's Publicly-owned Native Forests for Wood Production: A Review of the Science Underpinning their Management* by Turner, Flinn, Lambert, Wareing and Murphy (2011) are excellent compendiums of silvicultural knowledge for Tasmania and Victoria.
- This project would review silvicultural terminology used for native forestry in Australia and develop a standardised classification and terminology.

Anticipated gains:

- A standardised classification and terminology for Australian native forestry.

Potential proponents for project development

- FCNSW
- FPC
- Vicforests
- STT
- QDAF
- UniMelb
- ANU
- Southern Cross UniversityUTAS

Reference:

Ashton, M. and Kelty, M. (2018). *The Practice of Silviculture: Applied Forest Ecology*. Wiley. 758pp.

16. Training materials (procedural manuals/videos/apps) for native forest growers, employees and contractors)

Growers need employees and contractors to be trained sufficiently to achieve best outcomes for the forests they are growing eg prescriptions for thinning.

- Growers are increasingly turning to technical training providers to train field foresters, eg in Certificate III in Forest Growing and Management.
- ForestWorks is a not-for-profit skills development organisation that develops and manage skills standards and qualifications. Training is delivered by a range of registered training providers in areas such as forest management, sawmilling and processing. About 300 students completed forestry related vocational education and training (VET) courses in forestry in 2016 (MPIGA and NFISC 2018).
- In Tasmania, the not-for-profit Arbre Forest Industries Training and Careers Hub was launched in March 2016. This organisation was created to promote careers within the forest industry, by providing a clear entry and learning path for potential employees, and by introducing potential employees to employers.
- Training providers need good materials on native forest silviculture to deliver effective training. This may include manuals and videos.
- Procedural manuals are OK for most States but need standardised terminology and to be cognisant of modern operating environments. The NSW *Native Forest Silviculture Manual* has been identified by FCNSW as needing revision. PFT's *Managing Your Dry Forest* was published in 1994 and due for revision.
- Videos can be a succinct way of getting key messages to students, staff and contractors. There needs to be high quality control to ensure messages are clear and consistent with silvicultural and regulatory requirements.
- This project would have two phases:
- 1. Engage an experienced silviculturist to liaise with public native forest growers, private native forest grower support agencies, universities and VET training providers to identify a prioritised list of current and potential training materials.
- 2. To develop new or revised training materials identified in phase 1 within budget constraints.
- The aim would be to deliver, or help deliver, at least one new or improved training material for each state by 2023.

Anticipated gains:

A prioritised list of training material needs. At least one new or improved training material for each state by 2023.

Potential proponents for project development

- FCNSW
- FPC
- Vicforests
- STT
- QDAF
- PFT
- PFSQ
- Local Land Services, NSW
- UniMelb
- ANU
- Southern Cross University
- UTAS

Forest & Wood Products Australia

Appendix 6. Research providers in native forest silviculture RDE from 2009 to 2018.

This list was derived from contributors to *Australian Forestry* over the last decade. In many cases, departments at institutions have had name changes; the latest name has been used. Note that much research has been done in collaboration with government agencies that are not primarily research providers. These agencies are not included.

Australian Institutions

- ARC Centre for Forest Value, University of Tasmania.
- Australian Bureau of Agricultural Resources and Sciences, Canberra, Australia.
- Centre for Ecosystem Management, School of Science, Edith Cowan University, Joondalup, Western Australia.
- Centre for Mined Land Rehabilitation, Sustainable Minerals Unit, University of Queensland.
- Centre of Excellence for Climate Change, Woodland and Forest Health, Murdoch University, Western Australia.
- Charles Sturt University, Wagga Wagga, NSW
- CSIRO Land and Water, Canberra, Australia
- Department of Biological Sciences, Macquarie University, NSW.
- Department of Geomatics, University of Melbourne, Victoria.
- Department of Parks and Wildlife, Western Australia.
- Department of Resource Management and Geography, University of Melbourne, Victoria.
- Environmental Department, Alcoa World Alumina Australia, Pinjarra, Western Australia
- Ergon Energy, Toowoomba, NSW
- Fenner School of Environment and Society, Acton ACT, Australia
- Fire Ecology and Landscape Risk, Strategy and Engagement, Department of Environment, Water, Land and Planning, Vic, Australia
- Forest Industries Research Centre, University of the Sunshine Coast, Maroochydoore, Qld, Australia
- Forest Science Centre, NSW Department of Primary Industries, Beecroft, NSW
- Forest Solutions, Benalla Victoria
- Geography and Spatial Sciences, University of Tasmania
- Institute for Applied Ecology, University of Canberra, Australia
- Department of Primary Industries – Forestry, Forest Science, Parramatta, NSW
- Parks and Wildlife Service, Toowoomba, Queensland
- Queensland Department of Science, Information Technology and Innovation, Brisbane, Australia
- Research and Development Branch, Forestry Tasmania (ceased in 2017)
- School of Applied Science and Engineering, Monash University, Churchill, Victoria
- School of Biological Sciences, Monash University, Clayton, Victoria
- School of Ecosystem and Forest Sciences, University of Melbourne, Vic
- School of Environment, Science and Engineering, Southern Cross University, Lismore, NSW, Australia
- School of Geography and Environmental Studies, University of Tasmania

- School of Life Sciences, University of Newcastle, NSW
- School of Natural Sciences, University of Tasmania
- Tasmanian Herbarium, Tasmanian Museum and Art Gallery, Tasmania

Overseas Institutions

- Alberta School of Forest Science and Management, University of Alberta, Edmonton, Canada
- Department of Biological Sciences, Southern Illinois, Edwardsville, Illinois, USA
- Department of Biology, Coral Gables, Miami, Florida
- Faculty of Environment and Natural Resources, University of Freiburg, Germany
- Faculty of Forestry University of British Columbia, Vancouver, Canada
- Faculty of Forestry, University of Applied Sciences, Freising, Germany
- Institute of Sciences, University of Freiburg, Germany