Australian Research Council

Centre for Forest Value

Project Outcomes

2016—2021

UNIVERSITY of TASMANIA

Australian Research Council CENTRE FOR FOREST VALUE

Australian Government
Australian Research Council

The Australian Research Council Training Centre for Forest Value

The Australian Research Council Training Centre for Forest Value (CFV) commenced in 2016. The aim of the Centre was to build research capacity within the forest and wood products sector and provide evidence-based research to industry identified problems. The Centre was funded through the Australian Research Council and through the support of industry partners including: Sustainable Timber Tasmania, Forico, Greening Australia, Private Forests Tasmania, Forest Practices Authority, Neville Smith Forest Products, SFM Environmental Solutions and Forest and Wood Products Australia.

The research program of the Centre was managed under four themes that spanned the forest products supply chain. The four themes focused on forest production, products and manufacturing, supply chain integration and information management, and socio-economics.

Across the four themes, the Centre directly funded 14 PhD students, 4 postdoctoral projects and supported numerous associated research projects and affiliated PhD students. Since 2016, Centre researchers have produced over 150 peer reviewed articles, and leveraged an additional $3.8 million in funding.

In 2021, the Australian Research Council funding for the Centre concluded and this document highlights key Centre outcomes produced by the PhD and postdoctoral researchers directly funded by the Centre, as well as highlighting the significance of the work to the forest and wood products industry. Further information on the full range of Centre projects and outputs can be found at:

https://www.utas.edu.au/arc-forest-value

From the Director

It has been a pleasure being involved in this iteration of the Centre for Forest Value. I am proud of the achievements of the students, postdoctoral fellows and staff and am confident that we have delivered impactful outcomes for the industry. I take this opportunity to thank all who have contributed to the success of the Centre.

I thank the ARC for providing a highly successful funding platform that brings universities and industry together to find real solutions to industry challenges. I thank the theme leaders, Professor Brad Potts, Professor Greg Nolan and Professor Paul Turner and the industry partners for their support, collaboration and time spent engaging with and guiding the students through their projects. I thank Dr Andrew Jacobs (Forico) as Chair of the Joint Advisory Committee and our partner committee members, Suzette Weeding and Dr Dean Williams (STT), Dr Elisa Raulings and Dr Neil Davidson (GA), Penny Wells (PFT), Dr Peter Volker (FPA), Andrew Morgan (SFM) and Chris Lafferty (FWPA).

Many behind the scenes contributions often go unnoticed, and I especially wish to thank Dr Mark Neyland as Centre Manager and Dr Thomas Baker who have significantly supported the Centre and myself in the last three years that I have been with the Centre. I have greatly appreciated their support and laughs. It would remiss of me not to mention and thank the previous two Directors of this Centre, Professor Jim Reid and Professor Mark Hunt who established the Centre and steered the ship onto its course of success. I am grateful for their continued contribution and mentorship.

Associate Professor Julianne O'Reilly-Wapstra, Centre Director

Assoc. Professor Julianne O'Reilly-Wapstra
Centre Director

Professor Mark Hunt
Centre Director/ Deputy Director

Professor Jim Reid
Centre Director/ Deputy Director

Dr Mark Neyland
Centre Manager

Contents

Forest Production

This program explored the establishment, growth and management of forests planted for both restoration and production, and in particular the Australian hardwood estate. Research focussed on environmental, genetic and tree level traits. Studies in the production forest landscape examined the management of plantation hardwoods for their use in delivering a range of certifiable products including structural and engineered wood products. Restoration projects recognised the need for forest certification in forest management. These projects integrated forestry into a wider landscape context by considering ecosystem services, forest certification, business diversification and the role tree plantings can have in agricultural landscapes.

Research Staff:

Prof. Brad Potts
Chief Investigator

Prof. René Vaillancourt
Chief Investigator

Dr Peter Harrison
Postdoctoral Fellow

Dr Tanya Bailey
Postdoctoral Fellow

Dr Thomas Baker
Research Officer

PhD Researchers:

Zara Marais

Manuel Rocha

Nicolò Camarretta

Rose Brinkhoff

Vilius Gendvilas

Theses

Marais, Z (2021) A natural capital approach to agroforestry decision-making. University of Tasmania. Publication pending

Rocha, M (2021) Genetic and environmental controls of traits affecting profitability of pulp and solid wood production from plantation-grown Eucalyptus nitens*. University of Tasmania. Publication pending*

Camarretta, N (2020) Bridging the divide between remote sensing and forest ecological restoration: applications for effective monitoring. University of Tasmania. https://eprints.utas.edu.au/38368/

Brinkhoff, R (2021) Nutrient supplementation impacts on leaves, physiology and growth in mid-rotation Eucalyptus nitens*. University of Tasmania. Publication pending*

Gendvilas, V (2021) Thinning and fertiliser effects on Eucalyptus nitens wood properties. University of Tasmania. Publication pending

Understanding variation in wood quality properties

- **Wood quality variation can be predicted based on environment, stem position, genetics and silviculture.**
- **Results will help predict the amount of hardwood resource available for higher quality products.**

Important wood quality characteristics for solid wood products, such as density and stiffness, vary due to environmental conditions, genetics, silvicultural management and by position within the tree. Across multiple CFV research projects, we increased the understanding of how and why these wood quality traits differ in *Eucalyptus nitens,* in relation to these factors. Across multiple plantation sites, stiffness and density were shown to vary with temperature and rainfall variables, and while site differences explained a proportion of the variation in wood quality traits, individual tree variation was also significant. Stiffness varies longitudinally within individual trees, with stiffness being highest halfway up the stem. While density initially decreases with height, it increases again above approximately 7 metres in height. Silvicultural management practices also have a significant effect on wood properties, with thinning resulting in slightly less dense and less stiff trees. Results showed a correlation between tree and board stiffness, indicating that early non-destructive predictions of stiffness in standing trees may be used to segregate logs into different product streams. This research helps inform forest managers as to which parts of the estate are most suitable for production of particular wood quality characteristics, how management practices will affect wood quality and from what parts of the tree different products can be sourced. Using this information can help match the wood characteristics of logs to their optimum final product and therefore help maximise value.

Key Outputs:

Balasso, M., Hunt, M., Jacobs, A., & O'Reilly-Wapstra, J. (2021) Characterisation of wood quality of E. nitens *plantations and predictive models of density and stiffness with site and tree characteristics. Forest Ecology and Management. DOI: https://doi.org/10.1016/j.foreco.2021.118992*

Gendvilas, V., Downes, G., Neyland, M., Hunt, M., Harrison, PA, Jacobs, J., Williams, D., O'Reilly-Wapstra, J (2021) Thinning influences wood properties of plantation grown Eucalyptus nitens *at three sites in Tasmania. Forests 12, 1304 DOI: https://doi.org/10.3390/f12101304*

Rocha-Sepúlveda, MF, Williams, D, Vega, M, Harrison, PA, Vaillancourt, RE, Potts, BM (2021) Genetic variation of microfibril angle and its relationship with solid wood and pulpwood traits in two progeny trials of Eucalyptus nitens *in Tasmania. Holzforschung 000010151520200196. DOI: https://doi.org/10.1515/hf-2020-0196*

Vega, M, Harrison, PA, Hamilton, M, Musk, R, Adams, P, Potts, B (2021) Modelling wood property variation among Tasmanian Eucalyptus nitens *plantations. Forest Ecology and Management 491, 119203. DOI: https://doi.org/10.1016/j.foreco.2021.119203*

Vega, M, Hamilton, M, Downes, G, Harrison, PA, Potts, B (2020) Radial variation in modulus of elasticity, microfibril angle and wood density of veneer logs from plantation-grown Eucalyptus nitens*. Annals of Forest Science 77. DOI: https://doi.org/10.1007/s13595-020-00961-1*

5 mm cores used to calibrate the IML Resistograph (RESI), a tool to measure basic density

Measuring acoustic wave velocity in a standing tree as a proxy for wood stiffness
Photo: Vilius Gendvilas

Genetic variation in important wood quality traits

- **Key wood quality traits; microfibril angle, wood basic density, kraft pulp yield, are genetically based.**
- **These traits are critical for tree breeding in *E. nitens* & *E. globulus* to improve solid wood and pulp products.**
- **Comparing traits shows that breeding strategies for solid wood products and pulpwood are relatively compatible.**

Wood traits such as basic density, microfibril angle (MFA), modulus of elasticity (MOE), kraft pulp yield, stem straightness and acoustic wave velocity (AWV) are common breeding objectives in trees in order to produce logs suitable for solid wood products and pulpwood. CFV projects assessed genetic control of these traits and determined how this genetic variation was correlated across traits, particularly for those traits specific to solid wood production compared to pulp production. Results from these studies showed strong genetic control of the majority of these traits. Results also showed that many traits were correlated, for example MFA, a wood stiffness trait for solid wood products, was correlated with modulus of elasticity (MOE) and pulp yield. These results indicate that previous breeding to increase pulp yield is unlikely to have negatively impacted traits important for solid wood production. The work highlights the potential for using plantation *E. nitens* for solid wood products and may also aid in future breeding efforts to improve *E. nitens* and *E. globulus* genetic stock for both solid wood and pulp products.

Key Outputs:

Nickolas, H, Williams, D, Downes, GM, Tilyard, P, Harrison, PA, Vaillancourt, RE, Potts, BM (2020) Genetic correlations among pulpwood and solidwood selection traits in Eucalyptus globulus*. New Forests 137-158. DOI: https://doi.org/10.1007/s11056-019-09721-0*

Rocha-Sepúlveda, M. F., Williams, D., Vega, M., Harrison, P. A., Vaillancourt, R. E., Potts, B. M. (2021). Genetic variation of microfibril angle and its relationship with solid wood and pulpwood traits in two progeny trials of Eucalyptus nitens *in Tasmania, Holzforschung, 000010151520200196. DOI:* https://doi.org/10.1515/hf-2020-0196

Predicting basic density using drilling

- **The IML Resistograph tool can predict basic density of standing trees using drilling resistance.**
- **Research determined a more accurate model to convert resistograph measurements into basic density.**
- **Research also showed how this non-destructive tool can be used in research studies in place of traditional measurements.**

Measuring the resistance of tree stems to drilling using the IML Resistograph (RESI) is a non-destructive sampling technique used to calculate basic density in standing trees. Basic density is correlated with strength and stiffness, and is a good indicator of wood quality. Drilling resistance provides predictions of wood quality for both pulp and sawn wood. Recent work has improved the accuracy of converting drilling resistance values into basic density measurements. A comparison of drilling resistance to actual density measurements has allowed the non-linear response of the friction correction to be included in future predictions of basic density. CFV research also demonstrated the potential of drilling resistance as a measurement technique for silvicultural, genetic and ecological studies. As an example, RESI was used to calculate the genetic control of bark thickness in plantation *E. globulus.* These improvements could be used to generate more accurate models of basic density and highlight the capacity to gain better predictions of wood characteristics across forestry estates.

Key Outputs:

Downes, GM, Lausberg, M, Potts, B, Pilbeam, D, Bird, M, Bradshaw, B (2018) Application of the IML Resistograph to the infield assessment of basic density in plantation eucalypts. Australian Forestry 81, 177-185. DOI: https://doi.org/10.1080/00049158.2018.1500676

Gendvilas, V, Downes, GM, Neyland, M, Hunt, M, Jacobs, A. & O'Reilly-Wapstra, J. (2020). Friction correction when predicting wood basic density using drilling resistance. Holzforschung, 000010151520200156. DOI: https://doi.org/10.1515/hf-2020-0156

Nickolas, H, Williams, D, Downes, G, Harrison, PA, Vaillancourt, RE, Potts, BM (2020) Application of resistance drilling to genetic studies of growth, wood basic density and bark thickness in Eucalyptus globulus*. Australian Forestry 83, 172-179. DOI https://doi.org/10.1080/00049158.2020.1808276*

The use of natural capital accounting to value trees

- **Natural capital accounting is a useful tool for calculating the full value of planting trees on farms.**
- **This project highlighted the value of different tree choices aiding in decision making at establishment.**

Natural capital accounting (NCA) is a useful tool for valuing the wide range of services provided by agroforestry assets on farms. Traditionally, NCA is undertaken at larger landscape scales but this project evaluated existing tools and provided guidelines for measuring ecosystem services at smaller scales more relevant to individual farms. This work highlighted some of the key gaps in taking NCA to smaller scales such as the capacity to measure the condition of the asset and the role of species choice on the services provided. Results showed that species choice altered the types of services provided by agroforestry assets, for example, commercial monocultures provided greater carbon storage and wood production, but native shelterbelts provide better shelter and diversity. This project also provides a conceptual foundation for organisations who have an interest in applying NCA to demonstrating the farm-scale value of agroforestry, such as those interested in expanding timber estates into more agricultural landscapes or those trying to provide an economic basis for forest restoration and/or retention activities.

Photo: Zara Marais

Key Outputs:

Marais ZE, Baker TP, O'Grady AP, England JR, Tinch D, Hunt MA. A Natural Capital Approach to Agroforestry Decision-Making at the Farm Scale. Forests. 2019; 10(11):980.
DOI: *https://doi.org/10.3390/f10110980*

Effect of trees on microclimate in agricultural landscapes

- **Tree establishment in agricultural landscapes, e.g. windbreak, woodlots and woodlands, has significant impacts on microclimate e.g. by reducing windspeed by 50% and by reducing minimum temperatures.**
- **These changes can increase agricultural productivity and protect against extreme conditions.**

Trees in agricultural landscapes can serve a range of purposes from providing wood products, carbon storage and increasing biodiversity. Trees can also help increase agricultural productivity by mitigating extreme environmental conditions such as wind and extreme temperature. Centre for Forest Value studies examined the impacts that windbreaks and native forest woodlands can have on microclimates in agricultural landscapes. In both types of systems, the trees reduced the windspeed by around 50% and also had significant impacts on reducing extremely hot temperatures during the day and limiting extremely cold temperatures at night. These results have important implications for agricultural productivity by reducing the risk of extreme environmental conditions impacting crops and livestock and also through the potential to increase yields by providing better growing conditions. This research highlights the benefits of growing trees in agricultural landscapes.

Key Outputs:

Baker, TP, Moroni, M, Mendham, D, Smith, R, Hunt, MA (2018) Impact of windbreak shelter on crop and livestock production. Crop and Pasture Science 69, 785-796. DOI: https://doi.org/10.1071/CP17242

Baker, TP, Moroni, MT, Hunt, MA, Worledge, D, Mendham, DS (2021) Temporal, environmental and spatial changes in the effect of windbreaks on pasture microclimate. Agricultural and Forest Meteorology 297, 108265. DOI: https://doi.org/10.1016/j.agrformet.2020.108265

Understanding species and genetic performance in restoration plantings

- **Predicted climate change means that local genotypes of trees may not be those best adapted to a changed environment.**
- **This has important implications for selecting seed sources to use in restoration and new methods for selecting seed and provenances have been suggested.**
- **Selecting provenances from different climates may give an advantage in the future, however, contemporary growing conditions must be considered.**

The performance of species mixes and genetic stock across diverse environments is a major issue in restoration plantings as it impacts how successful restoration will be in both the short and long-term. The traditional approach to sourcing seed for restoration has often been one of 'local is best'. With climate change this may no longer be the case, and CFV researchers have developed and tested other strategies, such as climate-adjusted provenancing where genotypes from non-local populations are mixed with local genotypes. Many of these strategies are 'climate adjusted', that is, they involve sourcing seed from areas which are predicted to have analogous climates in the future and CFV research has created a framework to aid this decision making.

Photo: Tanya Bailey

In addition, CFV research projects have tested the success of using climate adjusted strategies for plant selection, for example, when non-local species or seed is used. One study tested the survival and growth of multiple families of two major eucalypt species grown with a variety of other plant species. Results showed that the variation in the co-planted species had little impact on the growth of eucalypts but that non-local eucalypt families were more prone to insect herbivory and frost damage compared to local eucalypt families. Results across the studies show that climate adjusted strategies may be beneficial in the future and should be considered along with contemporary growing conditions for restoration plantings.

Key *Outputs:*

Breed, M, Harrison, PA, Bischoff, A, Durruty, P, Gellie, NJC, Gonzales, EK, Havens, K, Karmann, M, Kilkenny, F, Lowe, AJ, Marques, P, Nevill, PG, Vitt, PL, Bucharova, A (2018) Priority actions to improve provenance decision-making. BioScience 68, 510-516.
DOI: https://doi.org/10.1093/biosci/biy050

Breed, MF, Harrison, PA, Blyth, C, Byrne, M, Gaget, V, Gellie, NJC, Groom, SVC, Hodgson, R, Mills, JG, Prowse, TAA, Steane, DA, Mohr, JJ (2019) The potential of genomics for restoring ecosystems and biodiversity. Nature Reviews Genetics 20, 615-628.
DOI: https://doi.org/10.1038/s41576-019-0152-0

Costa e Silva, J, Potts, B, Harrison, PA, Bailey, T (2019) Temperature and Rainfall Are Separate Agents of Selection Shaping Population Differentiation in a Forest tree. Forests 10, 1145. DOI: https://doi.org/10.3390/f10121145

Camarretta, N, Harrison, PA, Bailey, T, Davidson, N, Lucieer, A, Hunt, M, Potts, BM (2020) Stability of species and provenance performance when translocated into different community assemblages. Restoration Ecology 28, 447–458. DOI: https://doi.org/10.1111/rec.13098

Harrison, PA, Vaillancourt, RE, Harris, RMB, Potts, BM (2017) Integrating climate change and habitat fragmentation to identify candidate seed sources for ecological restoration. Restoration Ecology 25, 524-531. DOI: https://doi.org/10.1111/rec.12488

Monitoring restoration success and the use of unmanned aerial vehicles

- **Monitoring restoration success provides key information about future management and design.**
- **Restoration success varies depending on environmental conditions and species choice.**
- **Success also depends on the structural characteristics of the forest and this metric can be assessed efficiently using unmanned aerial vehicles (UAV).**

There is a clear need to monitor the success of restoration plantings to provide information about their success and to inform future management. Researchers showed that establishment success varies with species, year and lifeform. Measuring the structural attributes of a restoration planting can also determine its success or otherwise. CFV projects explored methods of analysing the performance of various species of trees as well as variation in performance based on genetic variation within species in restoration plantings. One project examined 25 different productivity and structural traits of the trees derived from UAV-based LiDAR. The results showed significant differences in traits due to species and genetics. Results of this project demonstrated the importance of species and genetic variation in determining the structure and productivity of restoration plantings. Importantly this project also showed that UAV based data collection can accurately depict structural attributes at the tree level and is a useful technique for monitoring the success/effectiveness of restoration plantings. This technique could be used in place of traditional field surveys which are often costly and time consuming.

Key Outputs:

Camarretta, N, Harrison, PA, Lucieer, A, Potts, BM, Davidson, N, Hunt, M (2020) From drones to phenotype: Using UAV-LiDAR to detect species and provenance variation in tree productivity and structure. Remote Sensing 12, 1-16. DOI: https://doi.org/10.3390/rs12193184

Camarretta, N, Harrison, PA, Bailey, T, Potts, B, Lucieer, A, Davidson, N, Hunt, M (2020) Monitoring forest structure to guide adaptive management of forest restoration: a review of remote sensing approaches. New Forests 51, 573-596. DOI: https://doi.org/10.1007/s11056-019-09754-5

Camarretta, N, Harrison, PA, Lucieer, A, Potts, BM, Davidson, N, Hunt, M (2021) Handheld Laser Scanning Detects Spatiotemporal Differences in the Development of Structural Traits among Species in Restoration Plantings. Remote Sensing 13, 1706. DOI: https://doi.org/10.3390/rs13091706

Jellinek, S, Harrison, PA, Tuck, J, Te, T (2020) Replanting agricultural landscapes: how well do plants survive after habitat restoration? Restoration Ecology 28, 1454-1463. DOI: https://doi.org/10.1111/rec.13242

Shackelford N, Paterno, GB, Winkler, DE, Erickson, TE, Leger, E, Svejcar, LN, Breed, MF, Faist, AM, Harrison, PA, et al (2021) Drivers of seedling establishment success in dryland restoration efforts. Nature Ecology & Evolution 5, 1283-1290. DOI: https://doi.org/10.1038/s41559-021-01510-3

Photo: Nicolo Camarretta

PhD researcher Nicolo Camarretta using remote sensing techniques to collect structural data

Informing revegetation policy and practice with research

- **An important part of the CFV revegetation work has been the translation of research into practitioner-focused resources that inform decision-making, policy, and management of revegetation plantings in the face of climate change.**

Equipping practitioners with the latest research to enable informed decision-making is critical to ensure revegetation plantings survive and eventually create sustainable populations in the face of climate change. Researchers from the CFV have been translating research outcomes and a decade of learnings from a network of restoration trials into practitioner focused resources aimed at delivering best-practice revegetation. This has been achieved through the publication of a Special Issue in the practitioner focused journal *Ecological Management & Restoration*, which summaries a decade of ecological restoration in the Tasmanian Midlands through 15 contributed papers, most of which were published by CFV staff and students, together with staff from the partner organisation Greening Australia. The learnings from establishing a network of field trials in the Midlands were developed into guidelines that assist with designing, planning, and implementing 'climate-ready' revegetation plantings across Australia, and included multiple workshops for researchers, practitioners, and policy makers across Victoria. Research from the CFV has also been used in the second edition of the FloraBank guidelines, the premier document used to guide and train Australia's ecological restoration community. This included informing best-practices along the seed supply chain, from seed sourcing, seed collection, and seed testing to seed production areas and database management.

Photo: Greening Australia

Restoration plantings in the Tasmanian midlands

Research from the CFV has also been used to inform practical policy for the forestry sector. This included refining and creating a new seed zone map for Tasmania. This modelling work enabled a broader scope for seed sourcing for forest revegetation, leading to more efficient forest management practices.

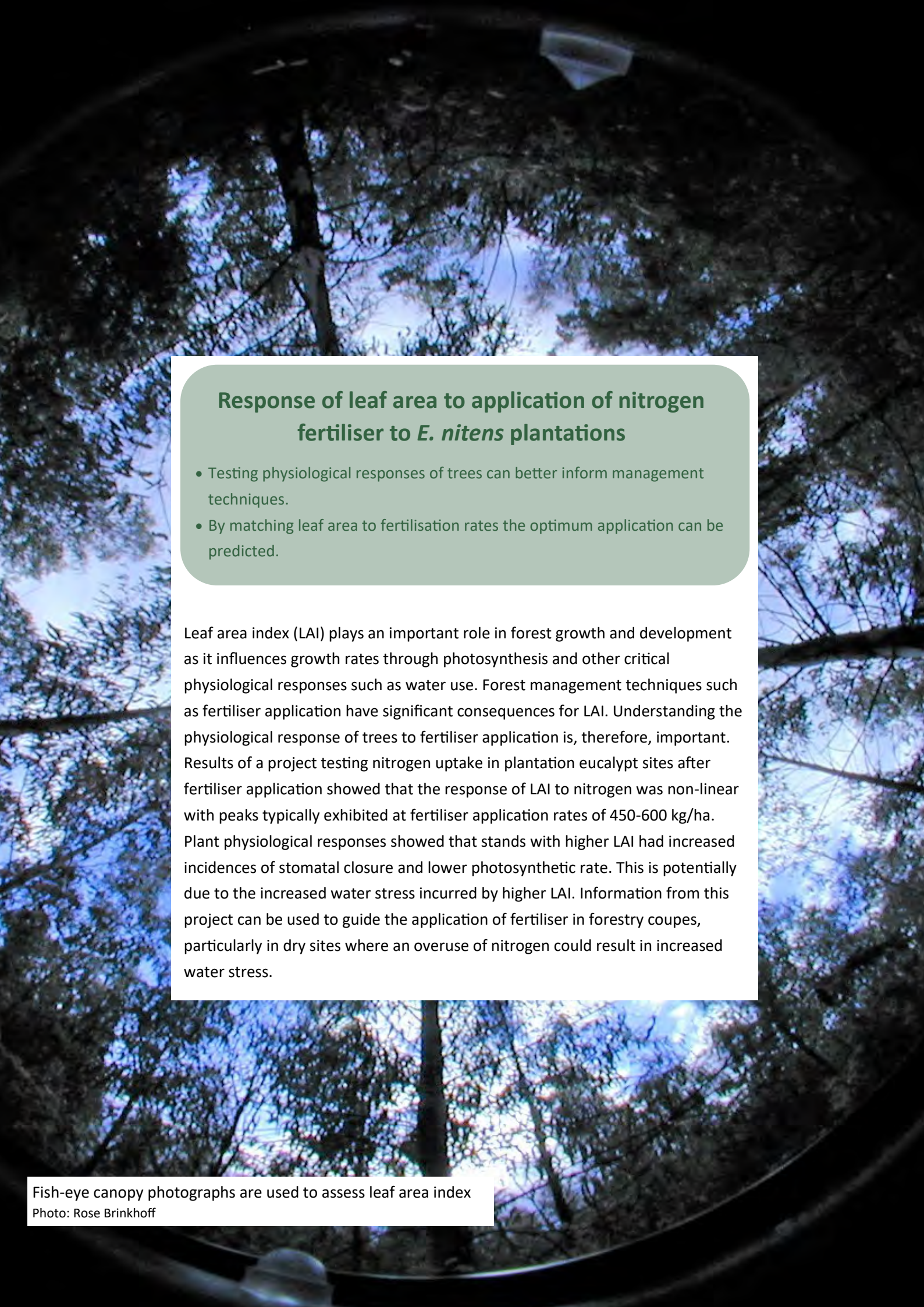
Key outputs:

FloraBank Guidelines (Ed LE Commander) FloraBank Consortium, Australia.
https://www.florabank.org.au/guidelines/)

Jellinek, S, Bailey, TG (2020) Establishing Victoria's Ecological infrastructure: A guide to creating climate future plots. Greening Australia and the Victorian Department of Environment, Land, Water and planning. Melbourne, Victoria.
https://www.greeningaustralia.org.au/wp-content/uploads/2020/02/GA0012_Climate-Plots-Document_SMALLER-SINGLE.pdf

Special edition (2021) Restoration of the Midlands of Tasmania. Ecological Management and Restoration.
https://onlinelibrary.wiley.com/journal/14428903

New Seed Zones adopted by industry (2020) University of Tasmania.
https://www.utas.edu.au/communications/general-news/all-news/new-seed-zones-adopted-by-industry



Response of leaf area to application of nitrogen fertiliser to *E. nitens* plantations

- Testing physiological responses of trees can better inform management techniques.
- By matching leaf area to fertilisation rates the optimum application can be predicted.

Leaf area index (LAI) plays an important role in forest growth and development as it influences growth rates through photosynthesis and other critical physiological responses such as water use. Forest management techniques such as fertiliser application have significant consequences for LAI. Understanding the physiological response of trees to fertiliser application is, therefore, important. Results of a project testing nitrogen uptake in plantation eucalypt sites after fertiliser application showed that the response of LAI to nitrogen was non-linear with peaks typically exhibited at fertiliser application rates of 450-600 kg/ha. Plant physiological responses showed that stands with higher LAI had increased incidences of stomatal closure and lower photosynthetic rate. This is potentially due to the increased water stress incurred by higher LAI. Information from this project can be used to guide the application of fertiliser in forestry coupes, particularly in dry sites where an overuse of nitrogen could result in increased water stress.

Fish-eye canopy photographs are used to assess leaf area index
Photo: Rose Brinkhoff

Products and Manufacturing

This program focussed on maximising the value of eucalypt logs. It examined the potential to convert plantation grown eucalypt trees into high value logs for use in appearance-grade solid timber and veneer products. It also considered the visual characteristics of the timber resource and compared it to the performance required in architectural design; developing methods for specification and performance testing that will enable the uptake of plantation eucalypt timbers for both generic building components and custom element manufacturing.

Research Staff:

Prof. Greg Nolan
Chief Investigator

Dr Nathan Kotlarewski
Postdoctoral Fellow

PhD researchers

Michelle Balasso

Kent Davis

Mohammad Derikvand

Theses

Balasso, M (2021) An investigation of Eucalyptus nitens *plantation wood quality to develop a segregation approach for diversifying resource utilisation. University of Tasmania. Publication pending*

Davis, K (2021) Methods to increase the efficient utilization of hardwood lumber to produce high value products. University of Tasmania. Publication pending.

Derikvand, M (2019) Optimising laminated high-mass timber components assembled from a fibre-grown resource for building applications. University of Tasmania. https://eprints.utas.edu.au/view/authors/Derikvand=3AM=3A=3A.html

Characteristics of plantation grown hardwood timber

- **Plantation eucalypts have traditionally been grown for fibre production, however, may be able to be adapted for solid wood products.**
- **Projects assessed the strength and visual characteristics of this resource for solid wood production.**

Interest in the use of fast-growing plantation hardwoods (eucalypts) for structural and solid wood products has increased recently. Researchers identified the potential of this plantation grown resource for applications such as mass engineered timber products. However, there was a lack of knowledge surrounding the physical, mechanical and machinability properties of this resource. To address this issue projects tested the mechanical properties of *Eucalyptus nitens* showing its modulus of elasticity (MOE), modulus of rupture (MOR), shear strength, compressive strength, cleavage and hardness. Machinability studies showed that this resource had an acceptable machinability quality which would enable it to be used in applications such as architectural interior products e.g. mouldings. In addition, projects used *E. nitens* and *E. globulus* boards sourced from plantations managed for fibre production and tested their visual characteristics, strength reducing features and structural characteristics. Results showed that the visual characteristics of boards such as knots, grain slope, checks, clearwood and insect traces were strong predictors of structural characteristics such as MOE and MOR. Information from these studies can be used to estimate structural performance of this resource and develop visual grading systems that reflect the structural characteristics. These studies also provide a strong foundation for the development of new applications and products from plantation grown hardwood timber.

Key Outputs:

Cheng, Y, Nolan, G, Holloway, D, Kaur, J, Lee, M, Chan, A (2021) Flexural Characteristics of Eucalyptus nitens *Timber with High Moisture Content. BioResources 16, 2921-2936. DOI: https://doi.org/10.15376/biores.16.2.2921-2936*

Derikvand, M, Kotlarewski, N, Lee, M, Jiao, H, Chan, A, Nolan, G (2018) Visual stress grading of fibre-managed plantation eucalypt timber for structural building applications. Construction and Building Materials 167, 688-699. DOI: https://doi.org/10.1016/j.conbuildmat.2018.02.090

Derikvand, M, Kotlarewski, N, Lee, M, Jiao, H, Nolan, G (2020) Flexural and visual characteristics of fibre-managed plantation Eucalyptus globulus *timber. Wood Materials Science & Engineering 15, 1-10. DOI: https://doi.org/10.1080/17480272.2018.1542618*

Derikvand, M, Kotlarewski, N, Lee, M, Jiao, H, Nolan, G (2019) Characterisation of Physical and Mechanical Properties of Unthinned and Unpruned Plantation-Grown Eucalyptus nitens *H.Deane & Maiden Lumber. Forests 10, 194. DOI: https://doi.org/10.3390/f10020194*

Derikvand, M, Nolan, G, Jiao, H, Kotlarewski, N (2017) What to do with structurally low-grade wood from Australia's plantation Eucalyptus; Building application? BioResources 12, 4-7. DOI: https://bioresources.cnr.ncsu.edu/resources/what-to-do-with-structurally-low-grade-wood-from-australias-plantation-eucalyptus-building-application/

Kotlarewski, NJ, Derikvand, M, Lee, M, Whiteroad, I (2019) Machinability Study of Australia's Dominate Plantation Timber Resources. Forests 10, 805. DOI: https://doi.org/10.3390/f10090805

PhD Researcher Mohammad Derikvand with *Eucalyptus nitens* logs at harvest
Photo: Mohammad Derikvand

Optimising mass-laminated timber products from plantation hardwoods

- **Nail-laminated timber floor panels produced from plantation grown eucalypts meet suitability requirements.**
- **This product can provide a high value product stream for plantation hardwood timber.**

Developing mass laminated timber products from the plantation eucalypt resource provides a useful product and diversifies the potential product stream. This project developed and tested nail-laminated timber (NLT) floor panels made from plantation grown eucalypts. The project showed there are some limitations in utilising solid wood from eucalypt plantations such as the presence of defects in sawn boards and the need for a grading system for plantation hardwoods. However, the NLT boards passed all strength and serviceability tests and were suitable for both residential and office buildings. Results from this project highlight that there is strong potential to have high-value products produced from the plantation eucalypt resource. Further development of products using the information generated from this project will enable the diversification of the product stream, including into mass-laminated timber products.

Photo: Mohammad Derikvand

Key outputs:

Derikvand, M, Jiao, H, Kotlarewski, N, Lee, M, Chan, A, Nolan, G (2019) Bending performance of nail-laminated timber constructed of fast-grown plantation eucalypt. European Journal of Wood and Wood Products, vol. 77, no. 3 , pp. 421-437. DOI: https://doi.org/10.1007/s00107-019-01408-9

Derikvand, M, Kotlarewski, N, Lee, M, Jiao, H, Chan, A, Nolan, G (2019) Short-term and long-term bending properties of nail-laminated timber constructed of fast-grown plantation eucalypt. Construction and Building Materials 211 (2019): 952-964. DOI: https://doi.org/10.1016/j.conbuildmat.2019.03.305

Selection and grading strategies for plantation *Eucalyptus nitens* sawn boards

- **Early selection of logs allows larger yield of stiffer boards.**

Stiffness is considered one of the most important structural properties for sawn timber used in buildings and laminated structures including mass timber components. The successful development of a plantation timber supply chain for structural products will depend on the accurate selection and grading of the resource. A project assessing stiffness of 268 sawn boards, traced from the tree through to final processing stages, shows strong, positive correlations between stiffness measured at each board processing stage through non-destructive testing (NDT) using acoustic wave velocity and the actual board stiffness measured through mechanical testing on dressed boards. Position of the board in the stem and sawn board processing treatment significantly impacted board stiffness, indicating that early selection of logs would allow larger yield of stiffer boards. The grading of boards using both the traditional Australian Standards visual-grading system (VGS) and NDT, identified a classification error of 82.5% and 45.2%, respectively. The VGS is not suitable for plantation grown *E. nitens* timber. A linear model was developed to re-classify the boards, providing a smaller classification error, including fewer boards being over-graded. This work shows NDT-acoustics can be used as an early selection method for structural boards and can also be employed to satisfactorily grade *E. nitens* plantation boards to be used in building structures and mass-laminated elements.

Key Outputs:

Balasso, M, Hunt, M, Jacobs, A, O'Reilly-Wapstra, J (2021) Development of Non-Destructive-Testing Based Selection and Grading Strategies for Plantation Eucalyptus nitens *Sawn Boards. Forests 12, 343. DOI: https://www.mdpi.com/1999-4907/12/3/343*

PhD Researcher Michelle Balasso testing wood quality

Photo: Michelle Balasso

Quantifying the appearance of solid wood plantation grown *Eucalyptus*

- **Research developed a method to digitally grade and sort plantation eucalypt boards based on appearance characteristics.**

Photo: Kent Davis

Utilising sawn boards from plantation grown eucalypts provides opportunities to diversify the products coming from this resource. However, such boards often contain a high proportion of natural growth features which under current grading guidelines categorises them into lower grades. Non-structural, appearance-based products may be suitable to be developed, however, the current grading guidelines are unsuitable for such products. This project developed a method to digitally capture the distribution of natural growth characteristics in plantation eucalypts. The project also examined techniques and guidelines for sorting boards to optimise appearance and size requirements and, therefore, optimise yields. Results from this project could be used to create grading standards for appearance plantation eucalypts as well as providing methods for millers to sort and cut boards for optimum value.

Key Outputs:

Davis, K, Kotlarewski, N, Orr, K, Nolan, G, Leavengood, S (2018) Optimizing Perception Oriented Classification of Sawn Boards from Fibre-Managed Plantation Resources. In '2018 Society of Wood Science and Technology/Japan Wood Research Society International Convention. Nagoya, Japan', 5-9

Thermo-hydro-mechanical treatment of eucalypts

- ***Eucalyptus* timber can be successfully densified using thermo-hydro-mechanical treatments increasing its potential to be used in higher-value applications.**

Thermo-hydro-mechanical (THM) and thermo-treatments are used to improve the properties of wood and diversify the potential uses of different species without the application of chemicals. This research showed that THM treatment can densify *E. nitens* eucalypt timber by 53% thereby improving stiffness and strength. This work highlights the potential of THM treatments to densify lower-grade plantation timber, raising the possibility of it being used for structural and other higher value applications. The research provides baseline information for the potential development of products using THM treatments.

Key Outputs:

Balasso, M, Kutnar, A, Niemelä, E.P, Mikuljan, M, Nolan, G, Kotlarewski, N, Hunt, M, Jacobs, A, O'Reilly-Wapstra, J (2020) Wood Properties Characterisation of Thermo-Hydro Mechanical Treated Plantation and Native Tasmanian Timber Species. Forests, 11, 1189.
DOI: *https://doi.org/10.3390/f11111189*

Supply chain integration and information management

This program aimed to transform business practices and performance through the development and integration of innovative new technologies. New sensor technologies enabled the collection of smart data across the value chain, providing the ability to record and track products from the forest to the end-user. A key focus of this program was to enhance resource grading, tracking and management by developing mechanisms for the flow of information across a traditionally fragmented forestry sector. This will improved resource utilisation, production efficiencies and enable value chain optimisation.

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Theses

Woo, H (2020) Forestry biomass residue supply chains in Tasmania: developing a digital tool and enhancing modelling to improve data accuracy, location mapping and impact assessments for future bioenergy. University of Tasmania https://eprints.utas.edu.au/35326/

Neagoe, M (2021) Investigating landside congestion at bulk cargo terminals in Forestry supply chains: A role for information systems. University of Tasmania. Publication pending

Krisanski, S (2021) Evaluating methods for the capture and analysis of digital and physical samples in complex forest environments. University of Tasmania. Publication pending.

Low-cost off-the-shelf unmanned aircraft systems for high resolution forest maps

- **Unmanned aircraft systems (UAS) are an increasingly valuable tool for gaining ground-based forest measurements and when combined with advance data processing they can replace manual forest mensuration techniques**
- **This project developed methods to capture detailed forest information using above and below canopy UAS, and to fully-automatically extract useful information from that complex data.**

UAS are powerful tools for capturing forest measurements efficiently and safely. This project developed techniques to use low-cost and easily available UAS to collect extremely high resolution point clouds of complex forest environments. This project also developed methods of fully-automatically extracting detailed and complex measurements directly from these point clouds. A Python package called the Forest Structural Complexity Tool was developed, which applies deep learning and computer vision techniques to the problems of point cloud analysis. These developments in remotely sensed forest measurement techniques could provide forestry and forest restoration organisations with an additional tool to capture forest measurements and enhance our capability to monitor forest structure in greater detail compared to traditional forest mensuration techniques.

Key Outputs:

Krisanski, S, Taskhiri, MS, Turner, P (2020) Enhancing Methods for Under-Canopy Unmanned Aircraft System Based Photogrammetry in Complex Forests for Tree Diameter Measurement. Remote Sensing 12, 1652. DOI: https://doi.org/10.3390/rs12101652

Krisanski, S, Taskhiri, MS, Gonzalez Aracil, S, Herries, D, Turner, P (2021) Sensor Agnostic Semantic Segmentation of Structurally Diverse and Complex Forest Point Clouds Using Deep Learning. Remote Sensing 13, 1413. DOI: https://doi.org/10.3390/rs13081413

Krisanski, S, Taskhiri, MS, Aracil, SG, Herries, D, Muneri, A, Gurung, MB, Montgomery, J, Turner, P (2021) Forest structural complexity tool— an open source, fully-automated tool for measuring forest point clouds. Remote Sensing 13, 4677. DOI https://doi.org/10.3390/rs13224677

Unmanned aircraft systems can fly beneath canopies to undertake forest measurements
Photo: Sean Krisanski

Canopy sampling drones

- Canopy sampling drones can provide a quick, efficient and safe mechanism for sample collection at tree crowns.

Sampling of forest canopies (e.g., for foliage or seed capsules) is often required for research and forest management. This project assessed the feasibility and development of drones for safely and efficiently sampling from the crowns of forest trees. This project developed and tested a series of novel UAS designs to safely and efficiently collect samples from almost any location on a tree. This step forward in forest sampling will likely enable the sampling of forest trees to be more efficient and safe, and in some situations may replace the use of traditional methods such as the use of tree climbers and cherry pickers.

Key Outputs:

https://www.media.utas.edu.au/general-news/all-news/award-helps-drone-project-reach-new-heights

Decision making for port congestion mitigation

- Port congestion affects terminal and transport operators, impacting turn-around time and fuel consumption.
- In the studied ports, terminal appointment systems were shown to be a more efficient way to decrease port congestion than options such as building extra infrastructure.

Photo: CFV

Factors leading to congestion at ports were identified using collected transport data, weighbridge data, and through surveys of organisations operating in the woodchip supply chain. The project identified major potential congestion issues including the lack of coordination across transport operators. This CFV project designed responses to congestion by developing a simulation model of a woodchip export terminal. Results showed that terminal appointment systems can often outperform other approaches such as increase port infrastructure. This information and model can be used to guide decision making on congestion management. Results from this work have already been implemented in some ports with booking systems and regular coordination meetings being implemented, resulting in a 20% reduction in congestion at a woodchip export terminal.

Key Outputs:

Neagoe, M, Hvolby, HH, Taskhiri, MS, Turner, P (2021) Using Discrete-Event Simulation to Compare Congestion Management Initiatives at a Port Terminal. Simulation Modelling Practice and Theory 102362. DOI: https://doi.org/10.1016/j.simpat.2021.102362

Neagoe M. Hvolby HH, Taskhiri MS, Turner P (2019) Understanding the Impact of User Behaviours and Scheduling Parameters on the Effectiveness of a Terminal Appointment System Using Discrete Event Simulation. In: Ameri F, Stecke K, von Cieminski G, Kiritsis, D.(eds) Advances in Production Management Systems. Towards Smart Production Management Systems. APMS 2019. IFIP Advances in Information and Communication Technology, vol 567. Springer, Cham. DOI: https://doi.org/10.1007/978-3-030-29996-5_3

Neagoe, M, Hvolby, H-H, Taskhiri, MS, Turner, P (2019) 'Modelling the supply chain impact of a digital terminal appointment systems parameters and user behaviours. A discrete event simulation approach.' Proceedings from the Australasian Conference on Information Systems. DOI: http://ecite.utas.edu.au/136036

Neagoe, M (2018) 'Exploring congestion impact beyond the bulk cargo terminal gate, Hamburg International Conference in Logistics.' Hamburg, Germany, 14th September pp 63. DOI: https://eprints.utas.edu.au/28934/

Optimising locations of biomass energy facilities

- Forest biomass can be utilised for energy generation, however, there needs to be a key understanding of the limitations in the supply chain.
- Studies identified the importance of limiting transport costs through drying and used models to predict where biomass plants would be most effective.

Forest biomass is potentially a valuable resource for energy generation, however, it is widely distributed across timber harvesting and processing sites. This makes the economic collection of the resource difficult and requires detailed planning and understanding of the key limitations in logistics. To optimise decision making about suitable locations for biomass energy plants in Tasmania, CFV projects used multi-criteria analysis (MCA) and GIS to develop models of where biomass plants could be located based on the distribution of the resource and supply chain cost analysis, as well as factors such as environmental and social considerations. Studies also reviewed the impact of key transport constraints such as bulk density, water content and energy content, and highlighted the importance of primary transport costs that could be reduced with techniques such as in-field drying. Studies highlighted the potential for the utilisation of biomass for energy generation in Tasmania particularly from logging residues. Additionally, results identified some key potential locations and also provided a decision-making framework that can be adjusted based on the importance of numerous factors. This project developed a program using harvester head data that tracked residue generation within forestry coupes in order to accurately predict where high densities of biomass were available. The program could be utilised as a management or planning tool for companies looking to more efficiently utilising within-coupe biomass.

Key Outputs:

Woo, H, Acuna, M, Moroni, M, Taskhiri, MS, Turner, P (2018) Optimizing the Location of Biomass Energy Facilities by Integrating Multi-Criteria Analysis (MCA) and Geographical Information Systems (GIS). Forests 9, 585. DOI: https://doi.org/10.3390/f9100585

Woo, H, Moroni, M, Park, J, Turner, P (2020) Residues and Bio-energy Generation: A Case Study Modelling Value Chain Optimization in Tasmania. Energy 196, 117007. DOI: https://doi.org/10.1016/j.energy.2020.117007

Woo, H, Turner, P (2019) A review of recent research on carbon neutrality in forest bioenergy feedstocks. Research Journal of Environmental Sciences 19, 556014. DOI: https://doi.org/10.19080/IJESNR.2019.19.556014

Strandgard, M, Turner, P, Mirowski, L, Acuna, M (2019) Potential application of overseas forest biomass supply chain experience to reduce costs in emerging Australian forest biomass supply chains – A literature review. Australian Forestry 82, 9-17.
DOI: https://doi.org/10.1080/00049158.2018.1555907

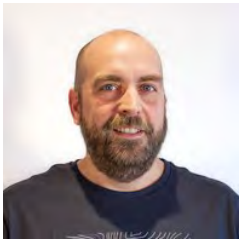
Forest biomass provides an available resource after harvesting operations
Photo: CFV

Forestry Socio-economics

This program focusses on the identification of the social and economic impact of forestry and forestry regulation. The program developed from an identified need from the forestry sector to better account for the benefits of changing forestry practices to enhance the social values associated with forest protection and to fully identify the costs to the forestry industry of implementing such protection. It aims to improve the total economic value of the forestry sector by developing frameworks with which to appropriately and systematically account for the full value of the forest sector in Tasmania.

This program is supported by the Forest Practices Authority and projects are still in progress. Updates on project outcomes will be found on the Centre website.

Research Staff



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Identification of the value of off-reserves in Tasmanian production forests

Off-reserves are areas outside the formal reserve system. These areas are negotiated with forest owners when developing forest practices plans. This project aims to utilise Ecosystem Service valuation techniques and Natural Capital Accounting to identify and account for the values associated with off-reserves. The focus of the research is on the value of the protection and enhancement of biodiverse ecosystems, cultural heritage, water resources and visual amenity which is provided by protection within production forests.

Investigating alternatives for the utilisation of forest residues

Forest residues are a currently underutilised resource which play an important role in improving biodiversity in recently harvested production forests, but these residues may also have economic uses. This project investigates public willingness to pay and forester willingness to accept compensation for the outcome of alternative management of forest residues. The project investigates how smoke, health impacts, biodiversity outcomes and employment within the supply chain impact upon public and forester preferences for alternative management of forest residues in Tasmania.

The use of Natural Capital Accounting in forestry

The theory of the use of Natural Capital Accounting (NCA) is well developed but in the forest sector very few real world applications can be identified outside broad-brush national applications. This project aims to develop upon Tasmania's position at the forefront of applied NCA to develop appropriate and applicable NCA frameworks for the forest industry. It will also identify data gaps and other barriers which limit the application of NCA and aim to fill these gaps in the context of the Tasmanian Forest Sector.

The Centre for Forest Value showcase evening, 2019
Photo: CFV

CFV Funding & Partners

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