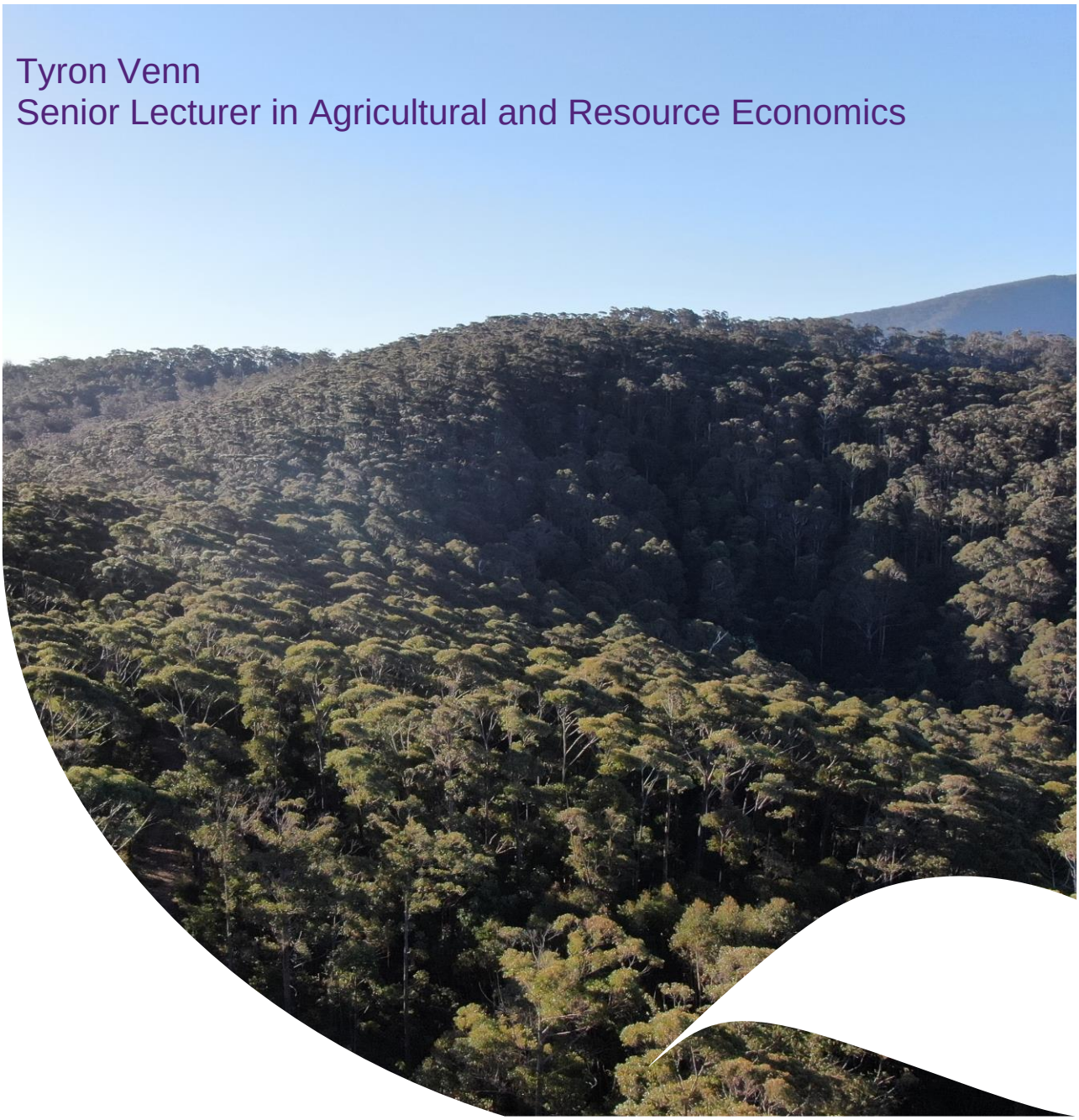
School of Agriculture and Food Sciences
13 December 2022

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA
CREATE CHANGE

Review of the Cost-Benefit Analysis of Native Forest Management by Frontier Economics and Andrew Macintosh

Tyron Venn
Senior Lecturer in Agricultural and Resource Economics



Review of the Cost-Benefit Analysis of Native Forest Management by Frontier Economics and Andrew Macintosh

Tyron Venn
School of Agriculture and Food Sciences, The University of Queensland, St Lucia, Qld 4072.

Highlights

- There are eight substantial problems with the cost-benefit analysis performed by Frontier Economics and Macintosh (2021) to compare forestry in the Southern and Eden RFA regions of New South Wales against a mountain bike recreation with strict conservation management alternative.
- Best practice in cost-benefit analysis for situations where evaluated projects differ enormously in scale was not followed by Frontier Economics and Macintosh (2021).
- Revised estimates that resolve some of the methodological errors and inconsistencies of the analysis by Frontier Economics and Macintosh (2021) revealed that transitioning the management of State Forests to strict conservation with mountain bike recreation would generate a net present value of -$252.43 million, indicating that forestry in southern New South Wales has a higher economic value for society.

Evaluation and Correction of the Frontier Economics and Macintosh (2021) Estimates of the Financial and Economic Performance of Mountain Bike Recreation with Strict Conservation

Frontier Economics and Macintosh (2021) performed a cost-benefit analysis over 30 years at a real discount rate of 7 % to evaluate the economic efficiency of transitioning State Forests in the Southern and Eden RFA regions of New South Wales from production of native forest hardwoods, to the provision of mountain bike recreation opportunities and strict conservation. They found the net present value of the mountain bike recreation and strict conservation alternative was $62 million greater than the forestry alternative. This result was largely due to the economic value of sequestered carbon. Currently there is no legal basis for carbon trading in Australia's production and conservation native forests. Therefore, the carbon values do not represent financial flows to government or southern New South Wales communities. They represent an estimate of the economic benefits of avoided future climate damage costs accruing to the global community arising from changes in forest management in Australia.

In brief, the main elements of the cost-benefit analysis performed by Frontier Economics and Macintosh (2021) were as follows. The forestry industry was projected to generate about $100 million in revenue per annum at a cost (e.g. including wages for sawmill employees) of about $80 million per annum, for a net annual benefit of $20 million. Mountain biking was expected to generate $0.75 million in total annual spending by visitors. It is unclear whether the spending of an expected 5000 local bikers was inappropriately considered as a benefit (since this would largely be a transfer of local spending within the community). The full costs of servicing mountain bike recreation were not provided in the analysis (see the next section). The economic value (not financial benefit) of the annual increase in carbon sequestration was estimated at about $20 million per year. Frontier Economics and Macintosh (2021) also included social health benefits for

increased mountain biking, but did not consider social health costs associated with the loss of hundreds of forestry jobs.

Frontier Economics and Macintosh (2021) performed a separate rudimentary employment impact analysis that is not useful for supporting decision-making. There are several problems with this analysis described below in the section on Employment Costs and Benefits. Their forestry direct employment estimate is substantially lower than any published estimate cited in their report. The analysis appears to exclude employment from processing of logs from State Forests in the Southern and Eden RFA regions at a sawmill in Victoria. Broad assertions were made that forestry workers made redundant will find alternative jobs in the region. The estimate of employment generated by a new mountain bike trail in southern New South Wales (50 to 100 jobs) largely captures *indirect* employment and so is not appropriate for comparison with *direct* forestry job losses. For the comparison to be valid, either only the *direct* jobs in mountain biking need to be considered, or the *indirect* job losses in other economic sectors supplying goods and services to the forestry businesses and their employees need to be included. Probably because of the absence of a consistent and rigorous employment impact methodology, Frontier Economics and Macintosh (2021) chose not to quantitatively estimate net employment outcomes.

The net present value (NPV) and benefit to cost ratio (B/C) investment criteria need to be interpreted cautiously when there are large differences in the scales of projects being evaluated (Boardman *et al.*, 2018). In these cases, other information should be presented to support decision-making by highlighting the enormity of the scale differences. This was not provided by Frontier Economics and Macintosh (2021). Table 1 reports an adaptation of the data used by Frontier Economics and Macintosh (2021) to highlight likely changes in production and employment for the Southern and Eden RFA regions of New South Wales arising from replacing forestry with mountain biking and strict conservation. Relative to continuation of forestry in the region, the gross value of production would fall by about 99 % ($99 million per year), and direct employment would fall by about 80 % (240 jobs) if the forests are managed for strict conservation and mountain biking instead. Condensing the analysis into a NPV hid the enormity of these differences, and the extent to which sequestered carbon is relied on for the mountain bike recreation and strict conservation scenario to surpass forestry.

Table 1. Supplementary criteria to support decision-making because of the large difference in scale of economic activity under the forestry and mountain bike recreation scenarios

Supplementary criterion	Forest management scenario in southern New South Wales		Absolute reduction in economic activity under the mountain bike recreation scenario	Percent reduction in economic activity under the mountain bike recreation scenario
	Forestry	Mountain bike recreation		
Gross value of direct production ($ millions per year) [a]	100	1	-99	-99%
Direct employment (number of jobs)				
Forest management and wood products processing [b]	300	50	-250	
Mountain bike recreation [c]		10	+10	
Total jobs	300	60	-240	-80%

Note: a. Gross values of direct production have been estimated from the analysis provided by Frontier Economics and Macintosh (2021).

b. 300 jobs is the middle of the range of estimates of current direct native forestry employment in the region asserted (but not substantiated) by Frontier Economics and Macintosh (2021). They indicated many workers in forest management, harvest and haul will find similar work if the forests are converted from working forests to strict conservation forests. Here, 50 jobs have been assumed.

c. Frontier Economics and Macintosh (2021) provided no estimate of direct employment in mountain bike recreation. Supporting evidence reported by Frontier Economics and Macintosh (2021) suggested about 3 to 4 direct jobs could be created in mountain bike trail maintenance. Here 10 trail maintenance jobs (that are separate from the forest management jobs) and other jobs directly supported by mountain biking demand (e.g. in mountain biking tourism business) have been assumed. If indirect employment in accommodation and hospitality sectors due to mountain biking is included, then reductions in sectors due to the decline of forestry businesses and workers also needs to be included.

Eight problems with the analysis by Frontier Economics and Macintosh (2021) have been identified, including: (a) an under-estimation of total carbon leakage to the atmosphere; (b) ignoring large direct costs associated with the mountain bike recreation and strict conservation scenario; (c) adopting inconsistent definitions of benefits and costs for the forestry and mountain bike recreation scenarios; and (d) adopting some parameter estimates on the basis of unsubstantiated assertions. Table 2 contrasts the base case findings from Frontier Economics and Macintosh (2021) against preliminary revised estimates made by Venn, which begin to resolve some of the methodological errors and inconsistencies of the original analysis. Strict conservation with mountain bike trails is found to have a net present value of -$252.43 million, indicating that State Forests managed for wood production in southern New South Wales have a higher economic value for society. There were omissions in the estimation of carbon leakage (described below). This means the carbon benefits of strict conservation are likely to be much lower than reported by Frontier Economics and Macintosh (2021). The original evaluation also failed to include the cost of an industry transition package that the authors had argued would be required, and did not correctly address the need for increased taxpayer funding of forest management due to the loss of timber revenues used by the forest management agency.

Table 2. The net present value of shutting down the native forest hardwood timber industry in southern New South Wales to manage State Forests for mountain bike recreation and strict conservation

	Description	Present value ($ millions)	
		Frontier Economics and Macintosh (2021)	Preliminary revised estimate by Venn
Benefits of mountain bike recreation scenario	Avoided costs of timber production	1071.58	1071.58
	Carbon abatement value	210.04	110.55[a]
	Recreation value	10.33	5.17[b]
Costs of mountain bike recreation scenario	Taxpayer funding of industry transition package	0	37.5[b]
	Taxpayer funding of forest management to replace foregone stumpage revenues from the sale of logs	0	172.24[b]
	Foregone timber industry revenues	1223.19	1223.19
	Cost of developing recreation	6.8	6.8
Net present value		**61.96**	**-252.43**

Notes: a. Frontier Economics and Macintosh (2021) assumed 5 % leakage. The preliminary estimate by Venn assumes 50 % leakage: 210.44/0.95 x 0.50. Please see the section below on **Carbon leakage from avoided harvesting in native forests** for further details.

b. See the section below on **Financial Costs and Benefits.**

Problems with the Analysis by Frontier Economics and Macintosh (2021)

The remainder of this document describes the eight problems with the cost-benefit analysis performed by Frontier Economics and Macintosh (2021), which biased the evaluation in favour of the mountain bike recreation and strict conservation alternative. These problems have been grouped into problems associated with estimated:

- Carbon leakage from avoided harvesting in native forests;
- Financial costs and benefits;
- Health costs and benefits; and
- Employment costs and benefits.

Carbon Leakage from Avoided Harvesting in Native Forests

Under-estimation of total carbon leakage to the atmosphere

1. Frontier Economics and Macintosh (2021) cited Whittle *et al*. (2013) to support their claim that leakages from southern New South Wales State Forests will be low; about 5 %. However, Whittle *et al.* (2013) explained that their '[e]*stimates of domestic leakage from avoided harvesting are based purely on domestic production leakage as measured by the change in the volume of logs harvested within Australia. Emissions associated with any substitution of wood for other materials such as concrete, steel or plastic are not included in the estimates*' (p. 5). Furthermore, Whittle *et al.* (2013) asserted that '*where domestic leakage is low, international leakage is likely to be high. While international leakage does not have direct implications for Australia's ability to meet its international emissions reductions targets, the implications for global greenhouse gas emissions will nonetheless be identical to that of domestic leakage*' (p. 4). That is, a tonne of carbon emitted external to Australia has the same damage cost for Australians as a tonne of carbon emitted within Australia. At the time of writing (December 2022), there are no policies in place within Australia that will eliminate international carbon leakage or domestic carbon leakage (e.g. due to substitution of native forest wood products with carbon-intensive alternatives such as steel, concrete and carpet). In addition, the mountain bike recreation and strict conservation scenario did not include policies designed to contract demand for construction and paper products.

   Whittle *et al.* (2012) suggested that high carbon leakage would be likely from avoided harvesting in public native forests producing large volumes of pulplogs, and made a policy recommendation to potentially not allow carbon credits for avoided harvesting of pulplogs because of the high risk of international leakage. From Appendix C page 50 of Frontier Economics and Macintosh (2021), 63% of the modelled future wood flows from the Southern and Eden RFA regions of New South Wales are pulplogs. Therefore, large carbon leakages from cessation of sawlog and pulplog production in southern New South Wales are likely. An average combined domestic and international leakage rate of 50 % has been assumed in the preliminary Venn estimate in Table 2 to better reflect carbon leakage to the atmosphere under the mountain bike recreation and strict conservation scenario.

The Intergovernmental Panel on Climate Change (IPCC) has long argued that forest management aimed at maintaining or increasing forest carbon stocks, while producing an annual sustained yield of timber, fibre and energy, will generate the largest sustained climate change risk mitigation benefit from forests (Metz *et al.*, 2007).

To a large extent, the opposing conclusions reached in the literature on carbon balances and forestry reflects the choice of carbon accounting framework. A life cycle assessment (LCA) takes into account all relevant carbon emissions and removals, which represents the best approximation of actual atmospheric impacts. The Kyoto framework does not account for carbon storage in landfill, avoided carbon emissions embodied in substitutes (e.g. steel, concrete and wood from unsustainably managed forests) and avoided fossil fuel emissions by using biomass for energy (UNFCCC, 2008; IPCC, 2013). The Australian National Carbon Accounting System (NCAS) does account for carbon stored in landfill, but not avoided emissions in substitutes and avoided fossil fuel consumption (Australian Government Department of Industry, 2020, 2021). The carbon analysis performed by

Frontier Economics and Macintosh (2021) is not an LCA, because it does not take into account all relevant carbon emissions and removals.

Researchers in Australia and internationally who have concluded managing forests for conservation will generate superior climate outcomes have typically adopted a partial carbon accounting framework, such as Kyoto (Colombo *et al.*, 2012; Dean *et al.*, 2012; Krankina *et al.*, 2012; Perkins and Macintosh, 2013; Keith *et al.*, 2014; Mackey *et al.*, 2020). Keith *et al.* (2015) adopted the LCA approach and concluded that no forest harvesting scenario could lead to a superior climate risk mitigation outcome than strict conservation in mixed eucalypt forests in New South Wales and mountain ash forests in Victoria. However, there are substantial issues with the data and analysis in this paper. Firstly, the evaluation only covered one harvest event, which fails to capture the long-term carbon implications of using forest products (Malmsheimer *et al.*, 2011). Second, the mountain ash scenarios appear to use the same data as Keith *et al.* (2014), with very high forest carbon estimates for unharvested forests that were driven by trees greater than 100 cm DBH. The authors of the allometric equation used in the study observed, 'Hollow regions of trunks, segments, and branches, which were prevalent in crowns of the oldest *E. regnans* trees… were not visible from the surface and remain unquantified' (Sillett *et al.*, 2010)(p. 988). There are no equations reported in Keith *et al.* (2015) that account for decay in large trees. Third, the product substitution impacts due to use of paper products were ignored, although these have been shown by Ximenes *et al.* (2016) to be substantial for mountain ash forests. Fourth, Keith *et al.* (2015) used a decay rate for wood in landfill far in excess of the rate recommended by the Australian NCAS framework and rates revealed by Australian empirical studies (Ximenes *et al.*, 2019).

Researchers who have adopted the LCA approach have typically found forests managed for timber generate net carbon sequestration benefits (Kaul *et al.*, 2010; Peckham *et al.*, 2012; Klein *et al.*, 2013; Oliver *et al.*, 2014; Sasaki *et al.*, 2016; Gustavsson *et al.*, 2017; Suter *et al.*, 2017; Morrison Vila *et al.*, 2021). LCA of forest management in northern New South Wales has revealed production forests will sequester more carbon over time than strict conservation forests (Ximenes *et al.*, 2012; Ximenes *et al.*, 2016). These findings are complemented by Australian research that has shown the lifecycle carbon emissions of detached houses in Australia can be halved by using more wood in their construction (Carre, 2011; Ximenes and Grant, 2013) and the lifecycle carbon emissions of midrise residential buildings can be reduced by one-third by using more wood (Jayalath *et al.*, 2020). In forest-poor Asian nations, including Taiwan, Japan and South Korea, Australian wood products for construction are considered among the most sustainable, and as having lower embodied carbon than equivalent wood products from the USA, China, Malaysia, Brazil and Russia (Li *et al.*, 2018).

Financial Costs and Benefits

Ignored substantial direct costs of the mountain bike recreation scenario

2. Frontier Economics and Macintosh (2021) commented at several places in their report of the need to compensate the industry for shut down, but they did not include this cost in their analysis. Using the Western Australian industry transition costing provided by Frontier Economics and Macintosh (2021), which was $50 million for 400 affected workers, it can be

argued that, if employment in the industry in southern New South Wales is 300, an appropriate package might cost about $37.5 million ($50 million/400 workers x 300 workers)[1].

3. It was correct for Frontier Economics and Macintosh (2021) to argue that stumpage prices are simply a transfer payment between sawmills and Forestry Corporation New South Wales when assessing the present value of forestry. The analysis made the assumption that forest management costs will be the same whether the forest is managed for multiple use or strict conservation with mountain biking. However, this does not mean ***net*** forest management costs for forestry and mountain bike recreation are the same. The revenue from the sale of logs can no longer be used to cover forest management costs under the mountain bike recreation scenario, so this must increase net forest management costs under the mountain bike recreation scenario.

   Foregone stumpage revenues under the mountain bike recreation scenario have been estimated with a conservative mean weighted stumpage price of $30/$m^3$ and the mean annual log volume projections reported by Frontier Economics and Macintosh (2021) in Appendix D for 2022 to 2051, of 462,675 m^3. Average annual stumpage revenue to contribute to the costs of forest management would be about $13.88 million, which has a present value of $172.24 million over 30 years at a 7 % discount rate. These revenues are not available to support forest management in the strict conservation with mountain biking scenario.

Inconsistent definitions of benefits and costs for the forestry status quo and the mountain bike recreation alternative scenarios

4. The net direct forestry benefits (industry revenues minus costs of production) were evaluated, while the mountain bike recreation alternative was not net of all costs, only costs of the trails. From Table 17 in Appendix D (p. 59), it can be determined that total visitor spending (5000 visitors per annum, 50 % overnight stays) is projected to amount to $725,000/y. A large fraction of this spending would be for accommodation, meals and incidentals. For consistency with the forestry scenario, the analysis needs to be modified in either one of the following two ways:

   - the costs of providing goods and services to the visitors (e.g. the meals and accommodation) need to be accounted for and deducted from total visitor spending in the mountain bike recreation scenario; or
   - the expected reduction in total spending by forestry businesses and workers in southern New South Wales communities needs to be included as a cost of the mountain bike recreation scenario.

As a preliminary revised estimate of the net benefit of recreation, the costs of providing goods and services to recreationists has been approximated by halving the present value of recreation benefits reported by Frontier Economics and Macintosh (2021) in Table 2.

[1] This package does not provide funding to expand forestry elsewhere (e.g. plantation establishment). The Western Australian Government also announced an additional $350 million spend on plantation expansion.

Health Costs and Benefits

Inconsistent definitions of benefits and costs for the forestry status quo and the mountain bike recreation alternative scenarios

5. The mountain bike recreation and tourism development in the Southern and Eden RFA regions have been projected to generate health benefits of $1.61/km. It is not clear what the present value of health benefits of the mountain bike recreation scenario is, as it is reported in aggregate with other recreation benefits.

   For consistency, the analysis must consider potential health costs of shutting down the native forest hardwood industry. These are likely to include ongoing anxiety and mental health issues in hundreds of negatively affected households.

   Venn has made no attempt to resolve this methodological issue in Table 2.

Employment Costs and Benefits

Unsubstantiated assertion about the level of employment at risk from mountain bike recreation development

6. Frontier Economics and Macintosh (2021) asserted they 'have seen' estimates of the current direct employment in the hardwood sector in the Southern and Eden RFA regions of New South Wales of between 290 and 320 jobs (p. 35). No sources for this estimate were provided. The most recent published employment estimate cited by Frontier Economics and Macintosh (2021) was from 2016 census data, which suggested total industry employment was 130 % higher at about 700 jobs. The much lower employment figures adopted in the analysis needs to be justified.

Inconsistent definitions of benefits and costs for the forestry status quo and the mountain bike recreation alternative scenarios

7. The assertion that mountain bike recreation and tourism development in the Southern and Eden RFA regions would create 50 to 100 new jobs was based on non-peer-reviewed documents about Tasmanian and New Zealand bike trails that included *indirect* employment arising from tourist expenditure, e.g. in the accommodation and hospitality sectors.

   For consistency, an estimate of only the *direct* mountain bike recreation jobs is required, or the potential indirect employment costs associated with the reduction in demand for goods and services due to the loss of hundreds of forestry jobs needs to be included in the analysis.

8. The analysis accounts for 'exports' of health benefits to visitors (people living outside the region) from mountain biking inside the region. However, the costs of cessation of 'exports' of logs outside the region have not been accounted for. Frontier Economics and Macintosh (2021) reported a Wood Supply Agreement (WSA) of 18,500 m^3 of high-quality sawlogs per annum to 2030 to Ryan & McNulty in Benalla, Victoria, but appear to have confined the employment impacts of industry shut-down to the Southern and Eden RFA regions in New South Wales (page 35).

For consistency, the potential employment impacts of cessation of forestry on Ryan & McNulty needs to be included in the analysis. Based on high-quality sawlog volume (25,000 m^3/y) and employment (50) reported for Blue Ridge Hardwoods in Eden (on pp. 20-21), employment based on the resource from the Southern and Eden RFA regions has likely been underestimated by about 37 jobs (50 jobs/25,000 m^3 x 18,500 m^3) at Ryan & McNulty in Victoria.

References

Australian Government Department of Industry, Science, Energy and Resources,, 2020. Full carbon accounting model (FullCAM). In. Online repository for the FullCAM model and associated documentation, Australian Government Department of Industry, Science, Energy and Resources, Available at URL: https://www.industry.gov.au/data-and-publications/full-carbon-accounting-model-fullcam. Accessed 26 January 2022.

Australian Government Department of Industry, Science, Energy and Resources,, 2021. National Inventory Report 2019 Volume 2. In. Australian Government Department of Industry, Science, Energy and Resources, Canberra. Available at URL: https://www.industry.gov.au/sites/default/files/April%202021/document/national-inventory-report-2019-volume-2.pdf. Accessed 26 January 2022.

Boardman, A.E., Greenberg, D.H., Vining, A.R., Weimer, D.L., 2018. Cost-Benefit Analysis: Concepts and Practice. Cambridge University Press, Cambridge.

Carre, A., 2011. A Comparative Life Cycle Assessment of Alternative Constructions of a Typical Australian House Design. In, Melbourne. Available at: https://www.fwpa.com.au/images/marketaccess/PNA147-0809_Research_Report_Comparative-LCA_0.pdf. Accessed 7 January 2021.

Colombo, S.J., Chen, J., Ter-Mikaelian, M.T., McKechnie, J., Elkie, P.C., MacLean, H.L., Heath, L.S., 2012. Forest protection and forest harvest as strategies for ecological sustainability and climate change mitigation. Forest Ecology and Management 281, 140-151.

Dean, C., Wardell-Johnson, G.W., Kirkpatrick, J.B., 2012. Are there any circumstances in which logging primary wet-eucalypt forest will not add to the global carbon burden? Agricultural and Forest Meteorology 161, 156-169.

Frontier Economics, Macintosh, A., 2021. Comparing the value of alternative uses of native forest in southern NSW. In. Frontier Economics, Canberra. Available at URL: https://www.frontier-economics.com.au/documents/2021/11/comparing-the-value-of-alternative-uses-of-native-forest-in-southern-nsw.pdf/. Accessed 10 December 2021.

Gustavsson, L., Haus, S., Lundblad, M., Lundstrom, A., Ortiz, C.A., Sathre, R., Truong, N.L., Wikberg, P., 2017. Climate change effects of forestry and substitution of carbon-intensive materials and fossil fuels. Renewable and Sustainable Energy Reviews 67, 612-624.

IPCC, 2013. 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol. In. Intergovernmental Panel on Climate Change, Switzerland. Available at URL: https://www.ipcc.ch/site/assets/uploads/2018/03/KP_Supplement_Entire_Report.pdf. Accessed 26 January 2022.

Jayalath, A., Navaratnam, S., Ngo, T., Mendis, P., Hewson, N., Aye, L., 2020. Life cycle performance of cross laminated timber mid-rise residential buildings in Australia. Energy and Buildings 223, 110091.

Kaul, M., Mohren, G.M.J., Dadhwal, V.K., 2010. Carbon storage versus fossil fuel substitution: a climate change mitigation option for two different land use categories based on short and long rotation forestry in India. Mitigation and Adaptation Strategies for Global Change 15, 395-409.

Keith, H., Lindenmayer, D., Macintosh, A., Mackey, B., 2015. Under What Circumstances Do Wood Products from Native Forests Benefit Climate Change Mitigation? PLoS One 10, e0139640.

Keith, H., Lindenmayer, D., Mackey, B., Blair, D., Carter, L., McBurney, L., Okada, S., Konishi-Nagano, T., 2014. Managing temperate forests for carbon storage: impacts of logging versus forest protection on carbon stocks. Ecosphere 5, paper 75. http://dx.doi.org/10.1890/ES1814-00051.00051.

Klein, D., Höllerl, S., Blaschke, M., Schulz, C., 2013. The Contribution of Managed and Unmanaged Forests to Climate Change Mitigation—A Model Approach at Stand Level for the Main Tree Species in Bavaria. Forests 4, 43-69.

Krankina, O.N., Harmon, M.E., Schnekenburger, F., Sierra, C.A., 2012. Carbon balance on federal forest lands of Western Oregon and Washington: The impact of the Northwest Forest Plan. Forest Ecology and Management 286, 171-182.

Li, S., Wu, H., Ding, Z., 2018. Identifying sustainable wood sources for the construction industry: a case study. Sustainability 10, 139; https://doi.org/110.3390/su10010139.

Mackey, B., Kormos, C.F., Keith, H., Moomaw, W.R., Houghton, R.A., Mittermeier, R.A., Hole, D., Hugh, S., 2020. Understanding the importance of primary tropical forest protection as a mitigation strategy. Mitigation and Adaptation Strategies for Global Change 25, 763-787.

Malmsheimer, R.W., Bowyer, J.L., Fried, J.S., Gee, E., Izlar, R.L., Miner, R.A., Munn, I.A., Oneil, E., Stewart, W.C., 2011. Managing Forests because Carbon Matters: Integrating Energy, Products, and Land Management Policy. Journal of Forestry 109, S7-S50.

Metz, B., Davidson, O.R., Bosch, P.R., Dave, R., Meyer, L.A. (Eds.), 2007. Climate change 2007: Mitigation of climate change Contribution of Working Group III to the Fourth Assessment Report of the IPCC, Cambridge University Press,, Cambridge. Available at URL: https://www.ipcc.ch/report/ar4/wg3/, accessed 19 June 2020.

Morrison Vila, L., Ménager, M., Finegan, B., Delgado, D., Casanoves, F., Aguilar Salas, L.Á., Castillo, M., Hernández Sánchez, L.G., Méndez, Y., Sánchez Toruño, H., Solano, G., Zúñiga Mora, P., Ngo Bieng, M.A., 2021. Above-ground biomass storage potential in primary rain forests managed for timber production in Costa Rica. Forest Ecology and Management 497.

Oliver, C.D., Nassar, N.T., Lippke, B.R., McCarter, J.B., 2014. Carbon, fossil fuel, and biodiversity mitigation with wood and forests. Journal of Sustainable Forestry 33, DOI: 10.1080/10549811.10542013.10839386.

Peckham, S.D., Gower, S.T., Buongiorno, J., 2012. Estimating the carbon budget and maximising future carbon uptake for a temperate forest region in the U.S. Carbon Balance and Management 7, 8.

Perkins, F., Macintosh, A., 2013. Logging or carbon credits: comparing the financial returns from forest-based activities in NSW's Southern Forestry Region. In. Technical Brief No. 23, Australia Institute, Canberra. Available at URL: https://australiainstitute.org.au/wp-content/uploads/2020/12/TB-23-Logging-or-Carbon-Credits.pdf. Accessed 22 January 2022.

Sasaki, N., Asner, G.P., Pan, Y., Knorr, W., Dyurst, P.B., Ma, H.O., Abe, I., Lowe, A.J., Koh, L.P., Putz, F.E., 2016. Sustainable management of tropical forests can reduce carbon emissions and stabilize timber production. Frontiers in Environmental Science 4, doi: 10.3389/fenvs.2016.00050.

Sillett, S.C., Van Pelt, R., Koch, G.W., Ambrose, A.R., Carroll, A.L., Antoine, M.E., Mifsud, B.M., 2010. Increasing wood production through old age in tall trees. Forest Ecology and Management 259, 976-994.

Suter, F., Steubing, B., Hellweg, S., 2017. Life cycle impacts and benefits of wood along the value chain: the case of Switzerland Journal of Industrial Ecology 21, 874-886.

UNFCCC, 2008. Kyoto Protocol Reference Manual. On Accounting of Emissions and Assigned Amount. In. United Nations Framework Convention on Climate Change, Available at URL: https://unfccc.int/sites/default/files/08_unfccc_kp_ref_manual.pdf. Accessed 26/01/2022.

Whittle, L., Hug, B., Burns, K., 2012. Leakage from avoided harvesting in native forests under the Carbon Farming Initiative: A qualitative assessment. ABARES report to client prepared for the Department of Climate Change and Energy Efficiency, Canberra.

Whittle, L., Berry, P., Heyhoe, E., 2013. Leakage from avoided clearing and harvesting of native forests under the CFI: A quantitative assessment. Report to client prepared for the Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education, ABARES, Canberra.

Ximenes, F., Bi, H., Cameron, N., Coburn, R., Maclean, M., Matthew, D.S., Roxburgh, S., Ryan, M., Williams, J., Boer, K., 2016. Carbon Stocks and Flows in Native Forests and Harvested Wood Products in SE Australia. Project Number: PNC285-1112, Forest and Wood Products Australia, Melbourne.

Ximenes, F., George, B.H., Cowie, A., Williams, J., Kelly, G., 2012. Greenhouse gas balance of native forests in New South Wales, Australia. Forests 3, 653-683.

Ximenes, F., Grant, T., 2013. Quantifying the greenhouse benefits of the use of wood products in two popular house designs in Sydney, Australia. International Journal of Life Cycle Assessment 18, 891-908.

Ximenes, F.A., Bjordal, C., Kathuria, A., Barlaz, M.A., Cowie, A.L., 2019. Improving understanding of carbon storage in wood in landfills: Evidence from reactor studies. Waste Manag 85, 341-350.

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

CREATE CHANGE

Contact details

Tyron Venn
T +61 7 **3365 2174**
M +61 **0499 384 852**
E **t.venn1**@uq.edu.au
W https://researchers.uq.edu.au/researcher/17289

CRICOS Provider 00025B