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How can we grow the plantation estate and improve private native forest management in Australia? Silvopastoral systems provide a solution

The area of plantation forest in Australia has declined by more than 10% since 2011–12 (Whittle et al. 2019; Legg et al. 2021), with possible further losses following the 2019–20 bushfires. This is despite growing demand for wood products and their known ability to capture and store carbon. The agriculture and land-use sector has an important role to play in reducing greenhouse-gas (GHG) emissions to help meet national targets and international commitments (e.g. the Paris Agreement on climate change) and limit the increase in average global temperatures to 1.5°C. Estimates by the Australian Bureau of Agricultural Resource Economics and Sciences suggest that few or no new long-rotation hardwood plantations will be established under current policy settings and economic conditions and that high land prices preclude the establishment of new plantations on modified pasture land (Whittle et al. 2019). Although some new policy initiatives to encourage plantation investment have been announced since 2019 (e.g. the federal government's timber plantation grants worth AUD 86 million, and the Regional Investment Corporation Plantation Loans – RICPL – scheme), it will take some years before this translates into action on the ground and to the expansion of the plantation estate.

Even with large-scale new plantation investment, it will still take more than 20 years before the first small sawlogs are produced, with larger logs taking 30 years. Further, the availability of timber from public native forests has been reduced since 1990 with the creation of formal and informal reserves; by 2030, the national sustainable yield in public native forests is forecast to decline to around 38% of the level reported in the 1998 reporting period (i.e. 1992–1996; Montreal Process Implementation Group for Australia and National Forest Inventory Steering Committee 2018). So, what is the potential for increasing timber production in private native forest areas? In some regions of Australia, large areas of privately owned native forest have produced timber in the past, and some – particularly in northern Australia – are subject to livestock grazing. In 2015–16, an estimated 11.8 million ha of private native forest in Queensland and 7.2 million ha of private native forest in New South Wales (NSW) were not legally restricted from wood harvesting (Montreal Process Implementation Group for Australia and National Forest Inventory Steering Committee 2018), although these numbers overestimate the area available for timber harvesting. When considering only commercially productive forest types, Lewis et al. (2020) reported approximately 2.1 million ha of potentially harvestable private native forest in southern Queensland. From a forestry perspective, however, many of these forests are degraded and in a poor productive state. For example, Lewis et al. (2020) found that private native forests in Queensland and NSW have a high proportion of small and unmerchantable trees that are growing very slowly. Decades of high-grading – that is, the selective removal of the best-quality timber trees without follow-up silvicultural treatment – have undoubtedly contributed to the high proportion of small and unmerchantable trees at many sites (Ryan and Taylor 2006; Lewis et al. 2020). The potential of private native forests to provide timber products in the future, even with improved management, is therefore limited at present, but this is not well recognised by governments, landholders and society.

In addition to their role in carbon sequestration and GHG offsets, both the plantation estate and private native forests will be crucial if Australia is to meet its growing demand for timber while reducing its international ecological footprint due to imported wood products. This is even more the case because governments have announced their intention to phase out native forest harvesting on public land in Victoria, Western Australia and South East Queensland. Several measures may be needed to ensure ongoing supplies to the domestic timber industry. Silvopastoral systems (SPSs) – in either native forests or new plantations, or both – provide one such measure that is yet to be widely adopted in Australia.

Silvopastoral systems

SPSs provide an opportunity to improve the economics associated with plantation establishment and native forest management. They involve the intentional management of both livestock and trees (the term 'silvo' referring to the 'tree' component and 'pastoral' referring to the 'grasses' or 'grass and legume' component) on a given unit of land. The aim of SPSs is to optimise land productivity by producing fodder, forage, livestock, woodfuel and timber while conserving soil and nutrients through careful stock management (e.g. rotational grazing). Several variants of these agroforestry systems exist with varying management intensities; in some cases, cropping is also incorporated into the early phase of tree establishment. The economic, environmental and social benefits of SPSs have frequently been documented in the literature (e.g. Smith et al. 2022). SPSs have numerous environmental benefits, such as improved water quality, soil conservation, carbon sequestration and wildlife habitat conservation (Shrestha and Alavalapati 2004; Smith et al. 2022). They can improve the resilience of farms to climate change through income diversification, ameliorate the annual cashflow problems inherent in timber-growing, and increase farm incomes in the medium to long term.

Plantation forest

Previous periods of expansion in the Australian plantation estate were backed by government investment (e.g. the establishment of the softwood plantation estate from the 1960s to 1990) on government-owned land and by managed investment schemes (MISs) motivated by tax incentives, in which hardwood plantations were established between

1998 and 2010. Despite current indirect Australian Government assistance measures (e.g. the federal government's timber plantation grants and the RICPL scheme, referred to above) to encourage plantation establishment, it is unlikely that governments will directly purchase or lease land for broad-scale plantation establishment because of a limited supply of state-owned cleared land and the high purchase cost of privately owned cleared land with suitable rainfall and soils. Existing private landholders can potentially drive the establishment of new plantations because there is plenty of suitable land and the upfront cost of land purchase can be avoided. Although SPSs require some compromise for conventional plantation growers (i.e. lower tree stocking) and graziers (i.e. lower animal stocking), when combined over a harvest return interval they can provide favourable financial outcomes for land managers (Maraseni et al. 2009; Donaghy et al. 2010; Chizmar et al. 2020; Francis et al. 2022). This seems an obvious solution for graziers in regions where trees grow naturally and where some decline in pasture condition exists (e.g. due to nutrient run-down, overgrazing and the loss of topsoil), which is common over large areas of eastern Queensland and northern NSW. Several constraints affecting plantation establishment on private land have limited the adoption of SPSs, however, and these are discussed below.

SPSs may also provide opportunities for existing plantation forest estates. Forestry companies (e.g. African Mahogany Australia and HQ Plantations) have demonstrated an interest in the co-benefits that SPSs provide, such as a reduced need for weed control and lower wildfire risk. Forestry companies may choose to transition to SPSs when their plantations are due for thinning, particularly when a higher thinning intensity is needed in blocks with a high proportion of poorly formed or defective stems. Conversely, for some graziers, the benefits of SPSs are related to cattle production and wellbeing rather than to additional revenues generated by timber sales (Orefice et al. 2017).

Private native forest

When managed sustainably, there is potential for certain native forests to provide an ongoing timber supply without affecting biodiversity conservation or forest productivity values. Opportunities for SPSs are particularly relevant in previously cleared regrowth forests, the value of which for biodiversity conservation is typically much lower than remnant forest (Smith et al. 2015; Shoo et al. 2016). To demonstrate the potential of SPSs in regrowth forests, we use southern Queensland as an example. The *Vegetation Management Act 1999* defines native forests in Queensland as remnant regional ecosystems (Category B vegetation), regrowth regional ecosystems (Category C or R vegetation), or non-remnant ecosystems (Category X vegetation). Category X forests are not regulated by the Code of Practice (Department of Natural Resources and Mines 2014) and therefore any level of forest thinning or landclearing is permitted in these areas. The re-clearing of woody vegetation is common practice in Queensland. SLATS data[1] suggest that the clearing of Category X areas accounted for 477,390 ha in 2018–19, which was approximately 70% of the woody vegetation clearing in that period. Around 386,767 ha was woody vegetation older than 15 years with 20–50% crown cover.

The advantage of native regrowth forests is that little upfront cost (relative to the cost of plantation establishment) is needed to ensure tree establishment. For example, the exclusion of livestock grazing and fire for a couple of years might be sufficient where an existing seedbank or lignotuber pool exists. However, not all regrowth forest is suitable for commercial timber production, stand densities may be highly variable, and some ongoing management (e.g. thinning) will be needed. Nevertheless, Category X regrowth forests with timber species of commercial value cover a large area in southern Queensland. For example, mapping carried out by the Department of Agriculture and Fisheries in 2022 suggests there are 818,091 ha of Category X forest is in the Eastern Hardwoods and South East Queensland supply zones alone. Hence, these areas represent a significant opportunity to prevent carbon storage losses by avoiding clearing and growing a future timber supply. Unfortunately, most private native-forest owners are inclined to re-clear regrowth because of the need for ongoing returns from grazing or cropping and the sovereign risk associated with allowing previously cleared land to return to remnant forest status.

SPSs could provide an incentive for preventing the re-clearing of these areas when it can be demonstrated that grazing production can continue by managing the forest at a low tree stocking (e.g. 50–150 stems ha^{-1}). Even forests managed at these relatively low densities will sequester significant amounts of carbon relative to open pasture and annual cropping alternatives. For example, a native regrowth eucalypt forest with 50 stems ha^{-1} that are 50 cm diameter at breast height would contain a carbon stock of around 280 tonnes of CO_2-equivalent ha^{-1} in the above- and below-ground biomass. When this figure is multiplied by the area of land that could be returned to ongoing forest production in southern Queensland (i.e. the 818,091 ha of Category X forest), we quickly realise the potential benefits to the atmosphere – approximately 231 million tonnes of CO_2-equivalent sequestered on land that otherwise could be cleared, burnt and returned to pasture. Even if we assume a very low level of vegetation biomass of 22 tonnes ha^{-1} (Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education 2013), the clearing of 477,390 ha of Category X land in the SLATs 2018–19 reporting period would have resulted in the emission of around 19 million tonnes of CO_2-equivalent from that vegetation. Further carbon benefits through SPSs may be obtained by preventing soil carbon losses (through re-clearing for grazing), improving soil carbon stocks (e.g. De Stefano and Jacobson 2018) and reducing methane emissions using certain legume species (McSweeney and Tomkins 2015) in the forest understorey.

Some land managers already reap the benefits of selective timber harvesting and ongoing cattle production, with little reward for the carbon they are sequestering. The financial benefits of SPSs have been reported for both native and plantation systems in Queensland. Francis et al. (2022) used case-study simulations of various management scenarios in southern Queensland. The two scenarios with silvicultural treatments maximised the merchantable wood growth and

[1]https://www.qld.gov.au/environment/land/management/mapping/statewide-monitoring/slats/slats-reports/2018-19-report#section-about

generated higher net present values than all other scenarios, including re-clearing for grazing and the high-grading of unthinned forest. These simulations did not consider any benefits that might arise through a carbon market; hence, higher net present values might be possible when accounting for carbon benefits. A similar finding was reported by Maraseni et al. (2009) for an SPS in spotted-gum plantation forests near Kingaroy, Queensland.

Cattle-carrying capacity usually decreases over time as a forest matures because of increasing competition between the trees and pasture for light, moisture and nutrients (Scanlan 2002). Nevertheless, SPSs managed at low tree densities are financially optimal because the decline in pasture production is offset by periodic financial returns from timber (Francis et al. 2022). Co-benefits can also be associated with maintaining tree cover, such as reduced livestock heat stress. In addition, the productivity of these systems can potentially be improved further by 'low key' pasture establishment in the understorey of native forests (e.g. Cook and Grimes 1977) or through inter-row pasture establishment in plantations using locally suited shade-tolerant pasture species (e.g. Figure 1).

Barriers to adoption and potential solutions

There are several barriers to SPS adoption in Australia, leading many graziers to have negative perceptions of trees in their grazing systems (Fleming et al. 2019). These barriers can be categorised into three groups, as follows:

(1) *Economic barriers*, such as upfront costs; opportunity costs of foregone annual income from grazing and cropping; long payback periods after plantation establishment or native forest management (i.e. thinning), which is beyond the planning horizon of most

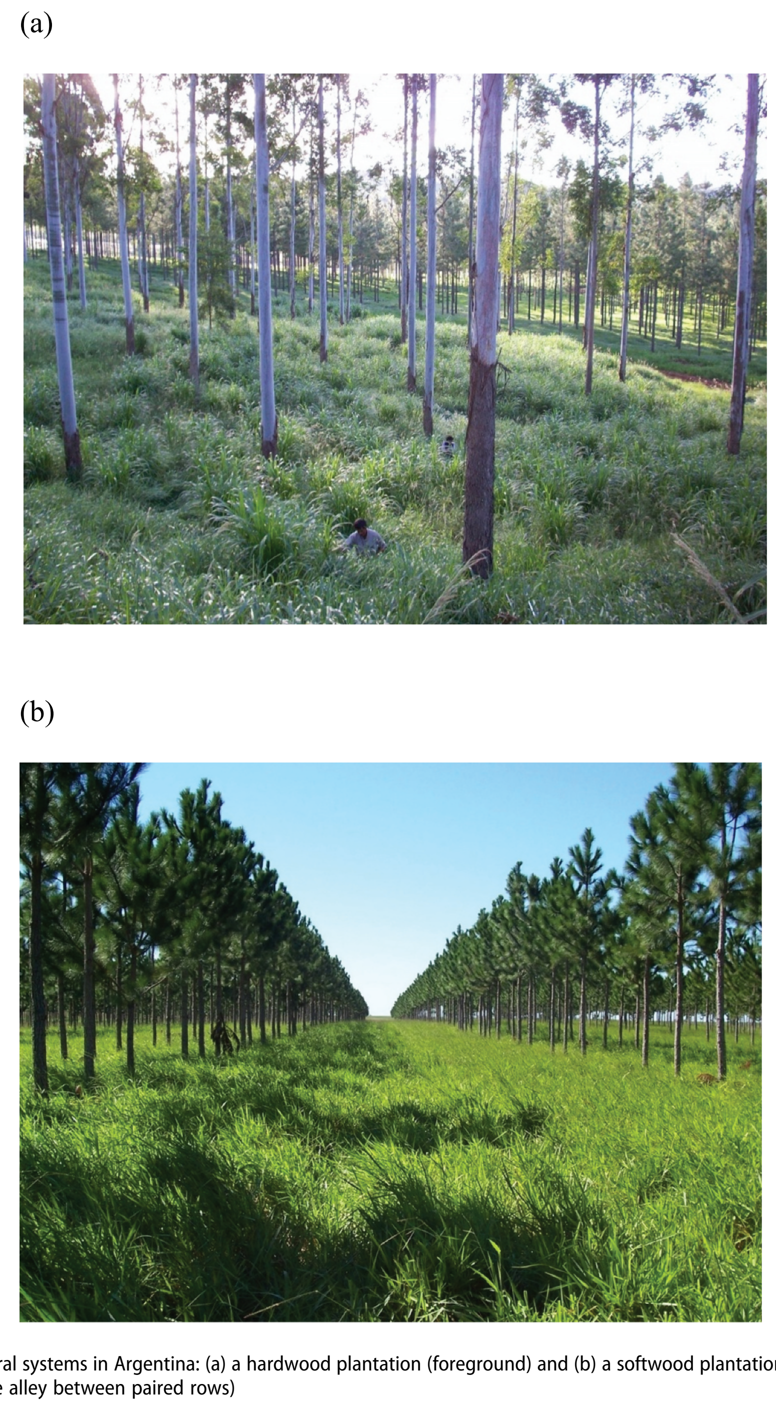

Figure 1. Examples of silvopastoral systems in Argentina: (a) a hardwood plantation (foreground) and (b) a softwood plantation, managed at a low stocking (e.g. double-row planting with a wide alley between paired rows)

landholders; a lack of transparency around the value of various timber products, making it difficult for landholders to make investment decisions; and limited opportunities for additional revenue streams based on the broader public benefits of managing domestic forests for timber (e.g. carbon sequestration and avoiding import-driven international forest degradation and deforestation). Landholders need a mechanism (e.g. certification systems) to demonstrate carbon-neutral livestock production to gain a price advantage (e.g. the Carbon Neutral Brazilian Beef protocol). There is also a lack of opportunity for easily gaining carbon credits from these systems in a native-forest setting because current methodologies for claiming Australian Carbon Credits Units do not recognise native forestry as a carbon-sequestering activity or carbon storage in native wood products.

(2) *Risk-related barriers*, such as sovereign risk – particularly in native forests, where landholders require certainty that if they invest money in forest management, they will be permitted to harvest their forests in the future; and the risk of plantation failure or loss due to pest, disease and fire – seen as real due to many examples in recent history in Australia (e.g. MIS hardwood plantation failures and recent bushfires).

(3) *Education-related barriers*, such as a lack of understanding of the benefits of SPSs and timber and carbon market values; and a lack of understanding of how to implement SPSs.

Graziers generally have a poor understanding of forestry but a thorough knowledge of their grazing enterprises. Regrowth eucalypt forests can become very dense without thinning, and active maintenance may be needed to ensure an optimal tree–grass balance. Landholders without forestry experience might need guidance on which trees to retain or thin and when to harvest trees that reach their maximum value. An opportunity for education through extension groups and government-funded programs exists. There is also potential for landholders to partner with timber companies and local sawmills to manage the timber component of their SPSs and secure markets for the timber. Decisions on which tree species to plant in different soils, climates and regions need to be carefully considered alongside an understanding of the target timber products. We should learn from the mistakes of the MIS plantations in Queensland and northern NSW, where tree species selection was not well matched to the biophysical environment and, consequently, thousands of hectares have been abandoned or returned to other land uses. Fortunately, the technical knowledge exists (e.g. from decades of research) to help guide landholder decision-making, although this information is not always readily available. Some further research is needed to guide appropriate SPS planting configurations and the species most suitable for SPSs.

Many cattle graziers realise they must adapt quickly to climate change, and income diversification through the inclusion of timber products may help them counter periods of drought and low cattle prices. Not all graziers will be in a financial position to invest in the implementation of SPSs, however, despite knowing the long-term benefits. Nevertheless, SPSs are applied successfully in subtropical and tropical environments in South and Central America (Figure 1) and have demonstrated carbon-sequestration benefits as well as improved land productivity. So why has adoption been more successful in other regions?

Various programs have encouraged SPS adoption in Latin America. For example, a payment scheme for ecosystem services has been implemented successfully in Costa Rica (Montagnini et al. 2013), and programs encouraging adoption also exist in Brazil, Colombia, Nicaragua and Peru. These are sometimes linked to government commitments to meet GHG reduction targets and in relation to concerns about deforestation (Montagnini et al. 2013; Chizmar et al. 2020). Projects such as the Silvopastoral Integrated Approaches for Ecosystem Management (2002–2007), the Colombian Sustainable Livestock Project (2010–2017), the Mainstreaming Biodiversity in Sustainable Cattle Ranching Project and the Network of Intensive Silvopastoral Systems have also provided technical support and incentive payments (Zepeda Cancino et al. 2016). We believe that government programs or incentives should be considered in Australia in which landholders who meet certain eligibility criteria might receive payments for the improved environmental management of their land, thus rewarding their contributions to reducing the need for environmentally damaging substitute products such as concrete, steel, plastics and imported tropical hardwoods.

Research providing a solution

Further work is needed in Australia to determine appropriate tree and pasture species in different environments, suitable planting configurations and spacings (e.g. double-row plantings with 10–20 m spacing between paired rows, Figure 1b) and appropriate native-forest densities to optimise productivity and ensure sustainable forest management. There is also a need to determine the biodiversity and GHG benefits of these systems relative to the alternative land-use option of open grazing land. Research is underway to better document the potential benefits of SPSs. For example, the Steak 'n' Wood project receives funding from Meat and Livestock Australia to support their goal of becoming carbon neutral by 2030.[2]

In summary, the widespread adoption of SPSs in Australia will require a combination of scientific innovation and economic incentives. Policy reform to encourage adoption of SPSs is needed to reduce sovereign risk and correct the failure of markets to better value the contribution that Australian forest-growers make to reducing the nation's international carbon and ecological footprint.

Disclosure statement

No potential conflicts of interest were reported by the authors.

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[2]https://www.mla.com.au/research-and-development/reports/2021/steak-n-wood-demonstrating-livestock-productivity-and-environmental-service-benefits-of-trees-on-farm-in-northern-systems/#

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