Carbon Sequestration in Native Rainforest Tree Plantations

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The recent rapid decline in tropical and subtropical forests and subsequent loss of biodiversity, coupled to the threat posed by climate change, has led to a requirement for sustainable forest systems. Large-scale monocultures supply timber that can no longer be harvested in sufficient quantity from natural forests in subtropical and tropical regions. However, there is a general perception that forest systems need to be managed to provide multiple production and environmental services, including carbon (C) sequestration, restoration of soil fertility, and biodiversity. Overall, traditional plantation monocultures cannot meet all of these new objectives, and native and mixed-species plantations may provide an alternative, when provision of ecosystem services, besides timber, becomes a priority.

The objective of this thesis was twofold. Firstly to assess C storage in native rainforest tree (hoop pine, *Araucaria cunninghamii*) plantations, planted as monocultures in subtropical Australia. Plantations were examined to evaluate their potential as a sustainable forest system for provision of high-value timber products and C sinks. The second objective was to contrast the traditional monoculture system with a multi-species system, and a mixed-species rainforest tree plantation was studied. These systems are receiving substantial attention from private forest growers as they could provide economic benefits, including greater productivity, coupled to biologically desirable outcomes, such as higher biodiversity. The focus of the second objective was to improve the design of mixtures for maximum wood production and C sequestration, so that other ecological benefits could be realised.

Subtropical native hoop pine monocultures did not store soil C into long-term storage pools as rapidly as adjacent native rainforest or pastures. In addition, substantial amounts of soil nitrogen were lost from tree plantations, indicating that with current management, these systems may not be sustainable in the long-term. Overall, total C storage, including soil and aboveground biomass

C, was higher in tree plantations than pastures highlighting the potential of native tree plantations for C sequestration.

The mechanisms behind lower soil C storage of native hoop pine plantations, compared with rainforest and pasture, may be related to differences in soil C stabilization. While native forest and pasture systems stored C within soil aggregates and through organo-mineral interactions, tree plantations did not show a strong aggregate hierarchy and most soil C was associated with mineral-sized particles. Because soil minerals have a limited capacity to adsorb soil organic C, they may limit the C storage capacity of the studied tree plantations. We conclude that changes to management of hoop pine monocultures, such as increasing plant diversity in tree plantations, may create conditions similar to the native forest and promote greater C sequestration in plantation soils by stabilization through both soil aggregation and organo-mineral interactions.

Since traditional monoculture forest production systems may not provide the multiple benefits needed for sustainable forestry, an alternative mixed-species tree plantation was investigated. We examined the dominant paradigm that mixtures of two fast growing species (*Grevillea robusta* and *Elaeocarpus angustifolius*) compete for site resources, while mixtures of shade tolerant (*Castanospermum australe*) and shade intolerant (*G. robusta* or *E. angustifolius*) species are complementary. Contrary to predictions, there was evidence for complementary interactions between the fast-growing species in terms of nutrient uptake, nutrient use efficiency and nutrient cycling. Preliminary model simulations of interactions between species for light indicated that *G. robusta* maintained the highest rates of photosynthesis under different light conditions and may be combined with *C. australe* and the more light demanding *E. angustifolius* in mixtures. Overall there was evidence for tree species combinations which could potentially sequester more C, in addition to other benefits including higher biodiversity and improved use of soil resources, in mixed-species plantations. Such knowledge is useful to encourage implementation of these new timber production systems.