Case Study
Soil carbon benefits through reforestation

Introduction

Changes in soil carbon occur slowly and the stability of soil carbon depends on environmental conditions and land management practices. Permanent crops such as trees are generally considered to sequester carbon in the soil, however there are few reliable datasets on soil carbon stocks and the transfer of carbon during reforestation.

The *Soil carbon benefits through reforestation* project aimed to determine soil and biomass carbon changes from reforestation across hardwood and softwood, savanna and rainforest ecosystems in subtropical and tropical Australia. The regions sampled included mixed species rainforest plantings in the wet tropics of North Queensland, spotted gum plantings in the Burnett and Scenic Rim regions of south-east Queensland, Pinus plantations in the south-east Queensland coastal lowlands and African mahogany in the Douglas Daly region of the Northern Territory and in Kununurra in Western Australia.

Project leader Dr Tim Smith, from the Queensland Department of Agriculture and Fisheries, said, "We did a total of 50 paired comparison sites across the tropical and subtropical areas. We spent a lot of time making sure the sites were on the same soil type, and had a similar slope and land-use history prior to reforestation.

"We also interviewed the land holders to see what anomalies may have turned up in the previous history of the sites."

The researchers compared pasture with reforested areas – as well as including three-way comparisons with remnant native vegetation areas where available – to quantify changes in soil carbon with land use.

They found that soil carbon levels had declined with land-use changes from remnant native vegetation to pasture, and that cultivation caused further declines. Reversing soil carbon decline through reforestation is a slow process; it typically takes more than 15 years for the soil carbon levels to exceed that of pasture.

Younger reforested areas had similar soil carbon levels to pastures, but older plantations had increased soil carbon (especially when organic matter was included) beyond the levels achieved with pastures.

"Substantially more carbon is stored in aboveground biomass with tree plantings, compared with pasture or cultivated land uses," Dr Smith said. "Therefore, reforestation is a viable option for maintaining or restoring soil carbon over the longer term and is an excellent management option for Australian agriculture, particularly in degraded land."

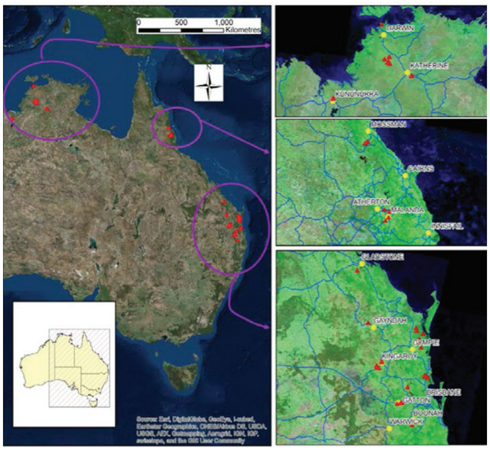

Figure 1. The regions sampled for the project included savanna areas in the Northern Territory and in Kununurra in Western Australia, mixed species rainforest plantings in North Queensland, spotted gum forest inland from the Burnett region, and pine forest in the coastal lowlands of Queensland.

Soil carbon and land use changes

A study based on a mixed species rainforest planting in northern Queensland showed there were significant losses of carbon associated with conversion of remnant rainforest to pasture. However, a change of land use from grazed pasture to a young rainforest plantation restored 21 per cent (+59t/ha) of the total lost carbon stock (122t/ha to 181t/ha) at an average yearly gain of approximately 8.4t/ha/year. While there was little change in soil carbon between land uses, there was an increase in belowground carbon due to the contribution of tree roots. Further analysis of the mixed rainforest species sites in north Queensland is needed to determine if there are changes in soil carbon as planting age increases.

The researchers compared native forest with pine plantations and found no significant changes in soil carbon over a 15-year period. Project leader Tim Smith said, "It's crucial in coastal lowlands to maintain our soil carbon, because soil carbon makes up a large component of the cation exchange capacity in these systems. In the case of land use change from native forest to pine forest, the outcomes for soil carbon are not so bad."

Sampling intensity

In addition to comparing soil carbon changes between reforested areas and previous land uses, the research team conducted sampling intensity studies, with a view to refining soil sampling techniques.

"Typically, there was mounding and other disturbances that created a great deal of variability on the sites where researchers were sampling soil carbon levels," Dr Smith said.

"We started our studies with three intensive sampling exercises to determine the optimum number of samples we needed to take to decrease our sampling error. We determined that a minimum of eight plots of 10 bulked soil cores were required to minimise sampling error in variable reforestation sites. 'Wetting-up' techniques were also needed for the dry kandosol sites in the Northern Territory to improve soil coring efficiency."

Economic analysis

The project also involved an economic analysis of the profitability of reforestation projects (conducted by Kate Coelli). This can help landholders make decisions about reforesting their land and demonstrate the potential of crediting carbon in both the soil and biomass of a forest.

This aspect of the project examined species including African mahogany, spotted gum (utilised for multiple building materials), and mixed-species environmental plantings.

The net present value (NPV) of the costs and benefits of each site was identified using the best guess estimates, including a discount rate of 8.7 per cent. To test the sensitivity of the resulting NPV to some key parameters, a sensitivity analysis was undertaken separately on five parameters at each site, with each parameter set at low and/or high levels, holding all other parameters at the medium (best guess) level. The low carbon price was set to zero to test for the scenario that there is no value of carbon, and the high value (originally $24) is the fixed price of carbon under the previous legislation.

As prices of carbon and timber both have the potential to greatly fluctuate over time, a risk analysis was conducted to simulate the annual variability of these parameters over the life of the project (up to 100 years). The results of the risk analysis demonstrated that at a discount rate of 8.7 per cent, stumpage price (the price paid for the right to harvest timber) caused the NPV to vary quite substantially from year to year, while carbon price had relatively little influence.

The results of the sensitivity analysis demonstrated that – irrespective of which parameters were changed – the NPV of the African mahogany site remained positive, while the NPV of the mixed environmental site remained negative (Table 2).

Table 1: Key parameters used in the cost-benefit analysis

a. General assumptions	*Value*
Permanence period (years)	100
Reporting frequency (years)	5
ACCUs sold (% of total)	100
Timber sold (% of total stumps)	100
All non-trunk AGB (branches and leaves) left on site (% of total tree)	55
Harvest age (years)	25
Establishment management ($/ha)	100
Carbon credit processing ($/t CO_2)	1
Auditing cost ($/audit report/ha)	10
Soil sampling cost ($/ha)	0
Carbon price ($/ACCU)	5.35

b. Site-specific assumptions	*African mahogany*	*Spotted gum*	*Mixed environmental*
Opportunity cost of land ($/ha)	781.8	781.8	0
Establishment costs ($/ha)	1821.37	2560.60	6508.28
Ongoing costs ($/ha)	1814.53	2321.6	0
Plantation density (trees/ha)	1000	1000	2500
Plantation biomass (determined using)	Allometric equation	FullCAM model	FullCAM model
Soil carbon sequestration (t/ha/yr)	0.96	N/A	0.57
Final harvest timber price ($/m^3)	494.26	62.33	
Commercial thin timber price ($/m^3)	247.13	58.18	N/A

Table 2: Results for sensitivity analysis (NPV)

		African mahogany	*Spotted gum*	*Mixed environmental*
			Discount rate (%)	
	Low	$53,364	$1290	–$5736
	Medium	$36,392	–$1443	–$5722
	High	$27,466	–$2846	–$5701
			Carbon price ($/t CO_2)	
	Low	$36,202	–$1983	–$6161
	Medium	$36,392	–$1443	–$5722
	High	$37,233	$452	–$4183
			Stumpage ($/m³)	
Commercial thin	Low	$18,396	–$3482	N/A
Commercial thin	Medium	$36,392	–$1443	N/A
Commercial thin	High	$41,218	–$410	N/A
Final	Low	$16,290	–$4045	N/A
Final	Medium	$36,392	–$1443	N/A
Final	High	$41,286	$1182	N/A
			Soil sampling cost ($/m³)	
	Medium	$36,392	N/A	–$5722
	High	$34,726	N/A	–$7388

* Carbon price set to $0 for low, $5.35 for medium and $24.15 for high.

For the spotted gum, the discount rate and final harvest stumpage price appeared to have the largest impact, resulting in positive NPVs. The carbon price had a less substantial influence, but resulted in a positive NPV with a carbon price of $24.15.

In the scenario, the financial viability of carbon forestry in commercial plantations is influenced less by the price of carbon and more by the value of the harvestable timber. Previous studies found significant variation in economic viability between case studies, with some sites even yielding a positive NPV despite a carbon price of zero, due to the value of the timber.

The results demonstrated that additional income through carbon credits or alternative sources (such as tourism as found in North Queensland) is required to provide viable returns for hardwood plantations and amenity plantings. High value species such as African mahogany were likely to provide economic returns to the grower.

Based on the current carbon prices and substantial costs, significant land use change to carbon forestry is unlikely. However, there may be financially viable options in other similar ventures without large establishment costs, such as through natural regeneration of forested areas.

Implications

"The project has allowed us to fill some large knowledge gaps related to soil carbon in tree-based systems in northern Australia," Dr Smith said.

Forest ecologist Tom Lewis soil sampling in the north Queensland rainforest.

"It gives some confidence to policymakers, industry groups and farmers that trees in the landscape can rebuild carbon stocks where they have previously been depleted.

"While the economic analysis showed borderline returns for growing hardwood species for the building industry, high-value species such as African mahogany certainly provide the opportunity for economic returns to the grower."

However, Dr Smith said the benefits of reforestation extended beyond economic considerations.

"We need to look at the strategic incorporation of trees in the landscapes to benefit agriculture," he said. "Rehabilitation of degraded land, windbreaks for crops, livestock shelterbelts, buffer zones for watercourses and wildlife corridors ... all of these are measures that – rather than impeding agriculture – contribute to its long-term sustainability."

More information: Tim Smith,
Queensland Department of Agriculture and Fisheries,
0427 820 894, tim.smith@daf.qld.gov.au

Acknowledgements: Tom Lewis, Scott Swift, Bruce Hogg, Janet McDonald, Neal Menzies, Bernhard Wehr, Brigid McKenna, Ram Dalal, Ange Woods, Katy Carroll, Kate Coelli, Neil Tindale, Lindsay Hutley, Cassie McMaster, Colleen Miller, Steve Harper, Zara Hall, Mila Bristow, Philippa Bryant, Luke Verstraten, Dotti Timms, Ben Francis, Michael Brand, Carmen Walker, Ian Last and Russell Vance.

For assistance with field work and sample processing: Lisa Scholz, Jeremy Corbin, Kaitlyn Andrews, Philippa Linley, Clint Cameron, Anton Zbornak, Jess Harper, Rhianna Robinson, Lisa Hunt, Joe McNeal, Corrine Duncan, Joel Fostin, Leanne Bridges, Doug Mohr, Martyn Eliott, Nicolas Ortodossi, Grant Nevison, Anthony Staniland, Mark Bonner. For assistance with laboratory analysis: Rob De Hayr, Dan Yousaf, Dr Angus Mcelnea, Sonya Mork, Joshua Hansen and David Appleton. For in-kind collaborations on VIS/NIR research: Jenny Sinclair and Roger Meder. For editing: John Huth.