The impact of conversion of pasture land to *Pinus radiata* plantation on soil carbon stocks and dynamics

Cheryl Poon[1], Bhupinder-Pal Singh[1], Annette L Cowie[1], Mark Adams[2]

[1]Forest Science Centre, Industry and Investment NSW, PO Box 100, Beecroft NSW 2119, Australia

[2]Faculty of Agriculture, Food and Natural Resources, The University of Sydney, NSW, 2006, Australia

Introduction

Afforestation is likely to expand in Australia and New Zealand in response to growing opportunities for forests to earn "carbon credits" under emissions trading. However, the issue of whether soil organic carbon (C) may decrease or increase after establishment of plantation on agriculture lands is unresolved. There is urgent need to systematically quantify the impact of afforestation on soil organic C stocks to ensure accuracy in C accounting for emissions trading.

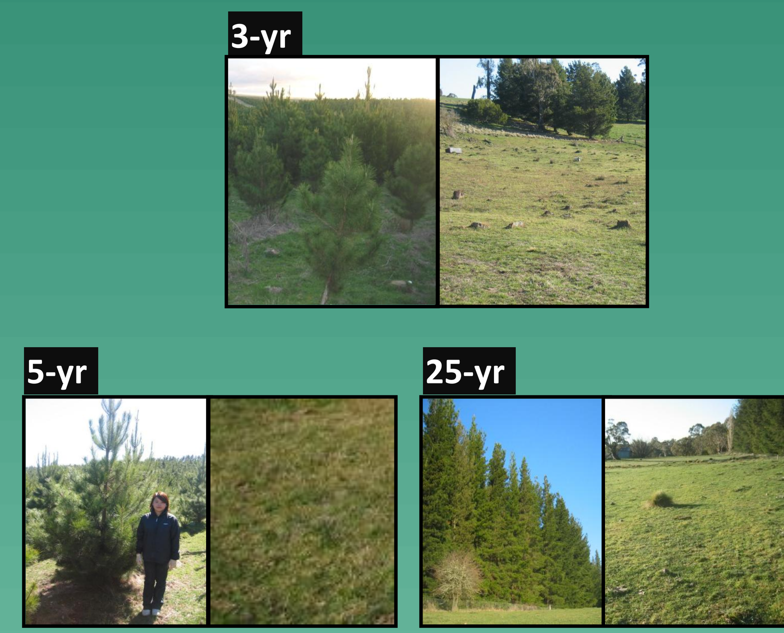


Figure 1. Paired pasture-pine sites of 3-yr , 5-yr and 25-yr after plantation establishment.

Table 1. Description of the paired pasture-pine plantation sites.	
Location	NSW, Australia
Species	*Pinus radiata*
Plantation age	3-, 5- and 25-yrs
Plantation history	1st rotation (3- and 5-yr sites) 2nd rotation (25-yr site)
Soil type	Kandosols
Climate	Temperate
Mean annual temperature	11°C
Annual Rainfall	860 mm

Aims

- To quantify the impact on soil C and nitrogen (N) stocks from conversion of pasture lands to *Pinus radiata* plantation.
- To quantify the influence of this land use change on relevant soil properties to better understand observed soil C dynamics

Methods

Sampling

- Three paired pasture-plantation sites of different ages (3-, 5- and 25-yr since establishment of plantation) were chosen from central tableland of New South Wales, Australia (Figure 1; Table 1).
- Each pair consisted of a *Pinus radiata* plantation and an adjacent pasture that had no change in its use since the establishment of the plantation.
- In Oct. 2008, soil samples were collected from the mineral layer at 4 incremental depths (0-5, 5-10, 10-30 and 30-50) (Fig. 2).

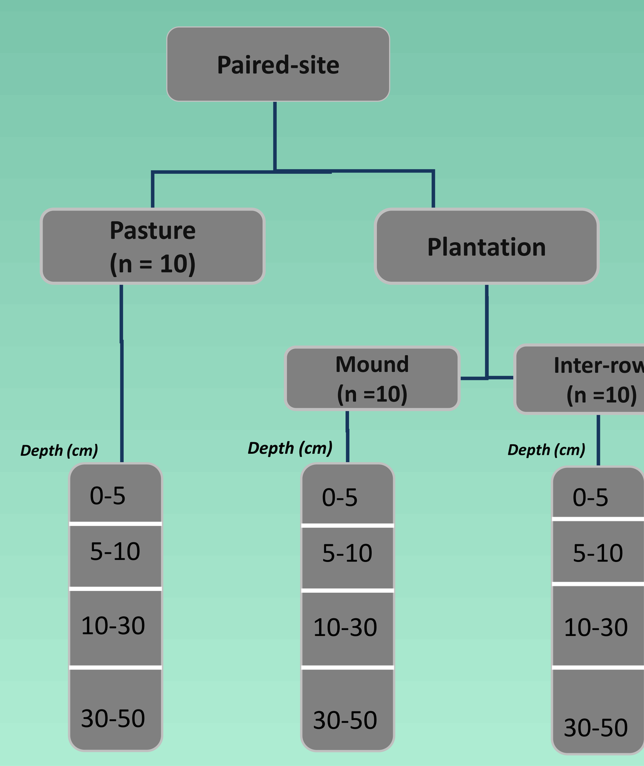
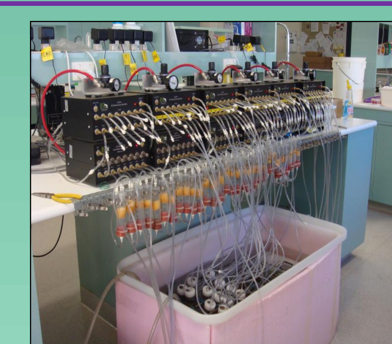


Figure 2. Soil sampling design within a paired pasture-plantation site. (n = number of soil cores).

Soil properties

Relevant soil properties were measured: bulk density, C%, N%, microbial biomass-C (fumigation-extraction method), heterotrophic soil respiration, and metabolic quotient (qCO_2 = respiration rate/microbial biomass).



Respirometer used for measuring heterotrophic soil respiration in the laboratory at 20°C.

Soil C and N stocks

1. **"Equivalent soil depth (ESD)"**
   Soil C and N stocks for each depth to 30 cm in pasture and plantation sites were determined using the corresponding C%, N% and bulk density data
2. **"Equivalent soil mass (ESM)"**
   We also estimated soil C and N stocks in pine plantations based on ESM to 30 cm depth in adjacent pastures and using polynomial interpolation to determine C and N concentrations in soil below the nominal 30cm depth.

Results

Soil C and N stocks

- Soil C stocks varied widely, from 64 to 106 t/ha, among sites.
- The younger pine plantations, 3-yr and 5-yr, had lower soil C stocks by 16% and 28%, respectively (by 15% and 23% respectively using the ESM approach) than the adjacent pastures; whereas the mature pine plantation, 25-yr after establishment of 2nd rotation pine, showed 15% higher (17% using the ESM approach) soil C stocks to 30 cm depth, as compared to the adjacent pasture (Fig. 3a upper pane).
- Soil N stocks were lower in all the three plantations than the adjacent pastures. Decreases in soil N stocks were pronounced in the 5-yr and the oldest plantation sites (25 to 30%) compared to the youngest plantation (5%) (Fig. 3b lower pane).

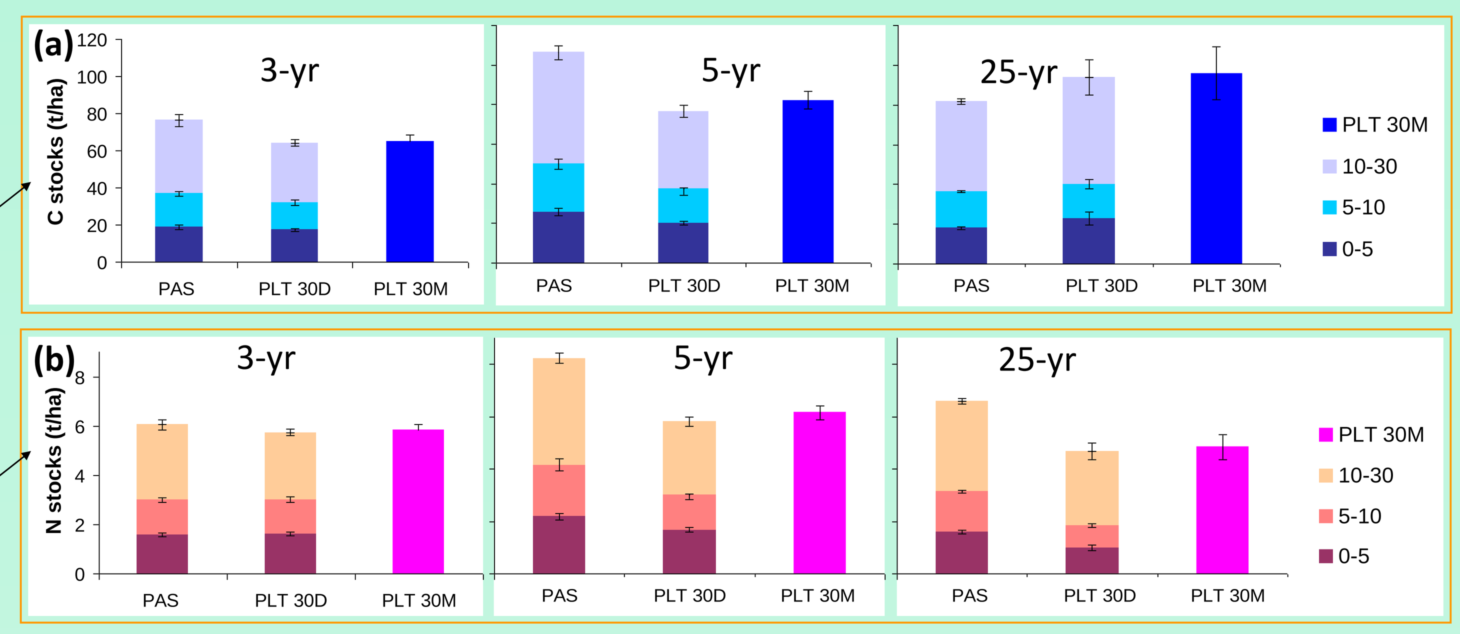


Figure 3: (a) Soil C and (b) N stocks in paired pasture-pine plantation sites. **PLT30D** represents C or N stocks determined using "Equivalent Soil Depth" to 30 cm in plantation; and **PLT30M** represents C or N stocks determined using "Equivalent Soil Mass" to 30 cm in adjacent pastures. Bars are standard errors (n=10)

Soil C and N stocks

- Soil C concentration decreased 5 years after conversion of pasture land to pine plantation, but was higher in the 25-yr old pine plantation than the adjacent pasture (Fig. 4a)
- Soil N concentration was lower in all the three plantations relative to the adjacent pastures (Fig. 4b)

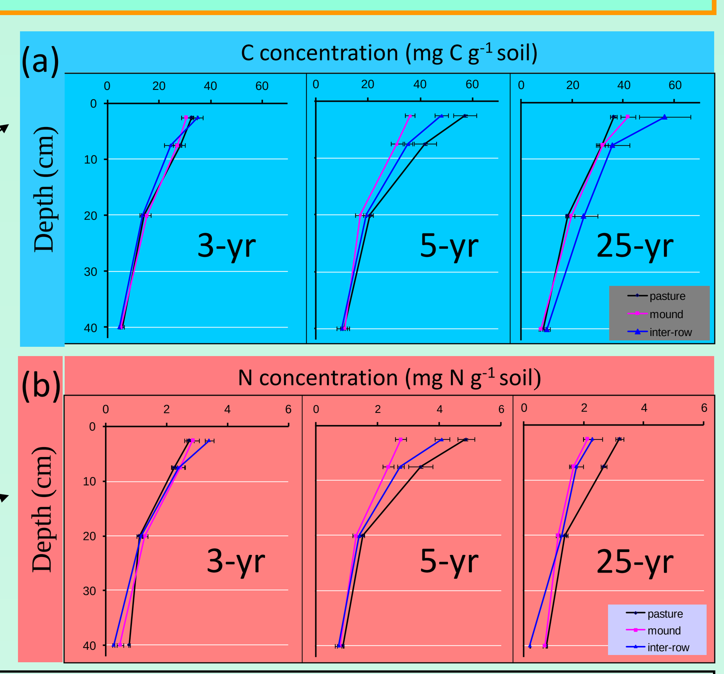


Figure 4: (a) Soil C and (b) N concentrations in pasture, plantation-mound and plantation-inter row at different establishment age and depths. Bars are SE (n=10).

Microbial properties

- Pools of microbial biomass-C were smaller (Fig. 5) and metabolic quotient qCO_2 greater (Table 2) in the 3-yr and/or 5-yr plantations compared to adjacent pastures.
- Rates of heterotrophic soil respiration were similar (plantation versus pasture) for the 3-yr and 5-yr plantations, but were faster at greater depths (5-10 cm and 10-30 cm) in the 25-yr pine plantation than the adjacent pasture (Table 2).

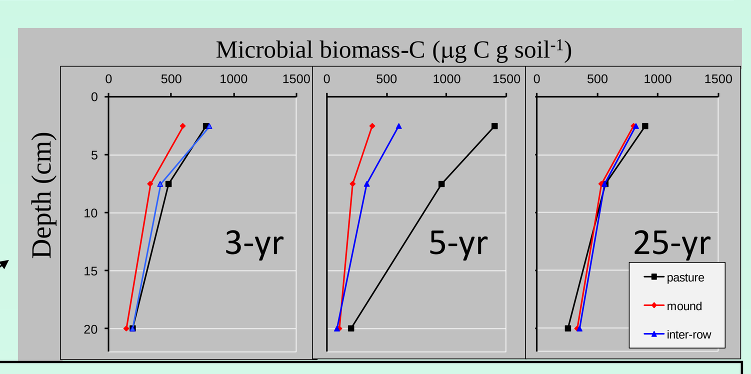


Figure 5. Microbial biomass C in paired pasture, plantation-mound and plantation-inter row at different establishment age and depths. Bars are SE (n=5)

Table 2.		Soil respiration rate ($\mu g\ CO_2$-C g^{-1} soil h^{-1})			qCO2 ($\mu g\ CO_2$-C μg^{-1} microbial-C h^{-1})		
Age	depth (cm)	Pasture	Mound	Inter-row	Pasture	Mound	Inter-row
3-yr	0-5	5.9±0.8	6.5±0.4	5.7±0.5	7.7±1.2	11.0±1.5	7.0±0.8
	5-10	3.1±0.3	3.2±0.2	3.2±0.4	6.5±0.7	9.6±0.2	7.7±1.4
	10-30	1.9±0.3	2.3±0.4	1.9±0.2	9.7±2.2	16.3±4.5	10.2±1.4
5-yr	0-5	5.8±0.5	3.7±1.1	4.6±0.6	4.1±0.6	9.8±1.7	7.6±0.8
	5-10	3.4±0.2	2.9±0.4	2.8±0.5	3.6±0.6	13.7±6.5	8.5±1.9
	10-30	1.9±0.3	1.5±0.2	1.9±0.3	9.6±1.8	14.3±3.6	22.0±3.3
25-yr	0-5	6.5±0.3	5.7±0.7	6.7±0.6	7.3±0.4	7.1±1.0	8.1±0.3
	5-10	3.0±0.2	4.4±0.3	4.5±0.4	5.3±0.7	8.1±1.8	8.0±0.9
	10-30	1.8±0.2	2.4±0.2	3.3±0.4	6.8±0.8	7.3±0.9	9.1±1.0

Conclusions

- **This study indicated that afforestation with *Pinus radiata* leads to changes in soil C and N storage.**
- **Soil C stocks may decrease, at least initially, while rates of C turnover were enhanced through microbial activity. Soil C will probably stabilise at greater concentration under mature pine plantation than pasture.**
- **Soil N stocks may also decrease due to removal of soil N into tree biomass and to enhanced mineralisation and losses of soil N, especially under younger plantations.**
- **Further detailed analysis of change in the dynamics of soil C and N, as affected by climate, soil type and land management, is still required for accurate quantification of net greenhouse mitigation potential of afforestation of pasturelands with pine plantations.**

Acknowledgments:

We would like to thank Megan Jenkins and Kamaljeet Kaur for providing technical support.