

Effects of plantation forest species on soil properties

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Abstract

Large scale afforestation of grasslands has occurred in New Zealand. Detailed investigation of changes in soil properties over time following establishment of different tree species is necessary to understand the impacts of this land-use change on soil nutrient dynamics and availability. A field trial was established in 1999 comprising 4 replicate plots of three commercial tree species (*Pinus radiata*, *Eucalyptus nitens*, *Cupressus macrocarpa*). Soil samples were taken from each plot prior to tree planting and after 5 years growth (2004). Analyses of samples taken in 1999 showed that the topsoil (0-5 cm) had a low pH (5.1), with low to medium levels of total carbon (5.01%), nitrogen (0.43%), phosphorus (630 mg/kg), sulphur (510 mg/kg) and exchangeable base cations (7.52 cmol_c/kg). Results for comparison between samples taken in 1999 and 2004 revealed a decrease in total C, N, P, S and exchangeable Ca and Mg confined to the 0-5 cm soil depth. The reductions were generally greater under *P. radiata* than *E. nitens* and *C. macrocarpa*. In contrast, inorganic and plant available Olsen P levels increased under all species. These findings confirm that afforestation of grassland has a major short-term impact on soil properties and processes.

Key Words

Grassland afforestation, soil fertility.

Introduction

Recent large-scale afforestation of pastoral farmlands represents a major land-use change in New Zealand. The area under short-rotation plantation forestry (mainly radiata pine (*Pinus radiata*)) doubled from 0.9 to 1.8 million ha (c. 7% total land area) between 1985 and 2005. Most of the established forests were planted on hill country areas developed under pastoral farming, where significant accumulation of organic matter and associated nutrients (nitrogen [N], phosphorus [P], sulphur [S]) occurred in these soils as a consequence of fertiliser inputs. This change in land-use was attributed to a combination of declining returns from pastoral farming and the expectation of increased future returns from forestry. In addition to the potential economic benefits associated with the establishment of conifer plantations, development of forestry in grassland areas may help to restore degraded lands and control soil erosion, especially in hill and high country areas (Davis 1998). It is commonly believed that conifers degrade soil fertility in various ways, although there has been little consistent scientific evidence for this (Binkley 1995). However, there is evidence from studies conducted in New Zealand that there may be some short term beneficial effects associated with the change in land use from grassland to forest such as increased phosphorus availability (Davis and Lang 1991; Belton *et al.* 1995; Chen *et al.* 2003). Most afforestation studies carried out to date in New Zealand have focused on the influence of radiata pine on soil properties and processes, and have involved paired site comparisons at one point in time, commonly 15-20 years after forest establishment (Chen *et al.* 2000; Chen *et al.* 2003). Closer examination of changes in soil properties over time following establishment of different tree species is necessary to understand the mechanisms responsible for changes in the soil organic matter and nutrient availability (Binkley and Högberg 1997) which in turn will assist in the development of effective long term strategies to maintain soil quality and fertility. The specific objective of this project was to quantify the effects of the different tree species on selected soil properties 5 years after planting.

Methods

Site description

Orton Bradley Park is located near Charteris Bay on Banks Peninsula, Canterbury, New Zealand. The afforestation trial was planted in pasture on lower north-east aspect slopes on Takahe silt loam (Fragic Pallic) soil formed in greywacke loess. The altitude is 40 m and mean annual rainfall is approximately 1000 mm. The trial area consists of 900m² plots comprising four replicates of three species (*Pinus radiata*, *Eucalyptus nitens* and *Cupressus macrocarpa*) arranged in a randomized block design of twelve plots each measuring 30 m x 30 m.

Soil sampling and analysis

Soil samples were taken by soil corer (6 cm diameter) at 4 depths (0-5, 5-10, 10-20, 20-30 cm) from each replicate plot immediately prior to tree planting in September 1999 and again in September 2004. Soil samples were air-dried and sieved <2 mm prior to determination of pH, total carbon (C), N, P, S, organic and inorganic P, plant-available P (Olsen P) and exchangeable cations.

Statistical analysis

Descriptive statistics and one-way ANOVA were carried out using Genstat 4.2 (Lawes Agricultural Trust, Rothamsted, UK) to calculate means and standard errors, and test for significant differences between means.

Results

Analyses of samples taken in 1999 showed that the topsoil (0-5 cm) had a low pH (5.1), with low to medium levels of organic carbon (5.01%), total N (0.434%), total P (630 mg/kg), total S (510 mg/kg) and total exchangeable base cations (7.52 cmol_c/kg). Comparison between samples taken in 1999 and 2004 revealed significant changes in organic matter and nutrient availability which were confined to the 0-5 cm soil depth (Table 1). The changes were generally greater under *P. radiata* than *E. nitens* and *C. macrocarpa*. For example, total C decreased by 16, 8 and 2% under *P. radiata*, *E. nitens* and *C. macrocarpa*, respectively, while corresponding decreases in total N were 17, 7 and 9%. Topsoil concentrations of organic P and total S also decreased under *P. radiata*, *C. macrocarpa* and *E. nitens* by 13, 7 and 11 and 8, 6 and 3 % respectively. In contrast, there were increases in inorganic and plant-available Olsen P in the 0-5 cm (42-62%) and 5-10 cm (62-100%) soil depth respectively. These data indicate that significant net mineralization of soil organic matter and organic N, P and S had occurred during the 5 years since tree establishment. On the other hand, soil pH levels and cation exchange capacity were largely unaffected by tree growth, while concentrations of exchangeable Ca and Mg slightly lower under all tree species in 2004 compared with 1999.

Table 1. Changes in selected topsoil (0-5 cm) properties determined prior to and five years after planting under different tree species. Data in columns are means (n=4); data in brackets are standard errors of the mean. * indicate significant differences ($P \leq 0.05$) between 1999 and 2004.

	1999	2004		
		<i>R. pine</i>	<i>E. nitens</i>	<i>C. macrocarpa</i>
pH	5.1 (0.04)	5.2 (0.07)	5.2 (0.09)	5.3 (0.09)
Total C (%)*	5.0 (0.13)	4.4 (0.07)	4.5 (0.20)	4.8 (0.14)
Total N (%)*	0.4 (0.01)	0.4 (0.01)	0.4 (0.02)	0.4 (0.02)
Total S (mg S/kg)*	510 (15)	445 (9)	465 (25)	458 (27)
Total P (mg P/kg)*	630 (28)	582 (39)	582 (56)	615 (64)
Inorganic P (mg P/kg)*	135 (7)	159 (6)	146 (18)	166 (17)
Organic P (mg P/kg)*	495 (22)	422 (34)	437 (38)	448 (55)
Plant-available P (Olsen P) (mg P/kg)*	13.4 (1.1)	20.8 (2.0)	16.7 (2.0)	21.6 (3.2)
Exchangeable Ca (cmol _c /kg)*	4.00 (0.18)	3.5 (0.12)	3.3 (0.25)	3.9 (0.28)
Exchangeable Mg (cmol _c /kg)*	2.8 (0.13)	2.5 (0.12)	2.7 (0.08)	2.8 (0.01)
Exchangeable K (cmol _c /kg)	0.4 (0.03)	0.4 (0.02)	0.5 (0.03)	0.5 (0.04)
Exchangeable Na (cmol _c /kg)	0.3 (0.02)	0.3 (0.03)	0.3 (0.01)	0.3 (0.05)

Conclusions

The findings of this study were consistent with previous studies, and confirmed that afforestation of grassland had a rapid and major impact on soil properties and processes. The apparent net reduction in topsoil total C and associated N, P and S can be attributed to a combination of factors including cessation of grazing, changes in organic matter and nutrient returns to soil under trees compared with grassland, and direct impacts of changes in the nature, distribution and activities of tree root systems compared with grassland.

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