

NOTES

Influence of adjacent stand on spatial patterns of soil carbon and nitrogen in *Eucalyptus* and *Albizia* plantations

Brent Ewers, Dan Binkley, and Michael Bashkin

Abstract: The chemistry and fertility of forest soils can be strongly influenced by tree species. Many studies have addressed the effects of monocultures on forest soil chemistry, but few have examined the effects of varying ratios of species within stands. In the absence of well-designed trials across a range of mixture ratios, we examined the spatial influence of adjacent stands on soil chemistry as a first approximation of the effect of mixed-species stands. We examined soil total carbon (C), nitrogen (N), and C/N along transects in adjacent, replicated, 12-year-old plantations of pure *Eucalyptus saligna* (Sm.) and pure N₂-fixing *Albizia falcataria* (L.) Fosberg. Soils from the center of the *Eucalyptus* stands had more C, less N, and higher C/N than soils from the center of the *Albizia* stands. The effects of the neighbor species were apparent for only about 5 m into the stands. This limited distance of the neighboring plot effect suggests that a species mixture ratio of 5:1 would be the highest ratio that would show any effect of the minor species on these soils.

Résumé : La chimie et la fertilité des sols forestiers peuvent être fortement influencées par l'espèce d'arbre. Plusieurs études ont évalué les effets de monocultures sur la chimie de sols forestiers, mais peu ont examiné les effets de différents rapports d'espèces à l'intérieur de peuplements. En l'absence d'essais bien effectués pour une gamme de rapports d'espèces, nous avons examiné l'influence spatiale de peuplements adjacents sur la chimie du sol comme première approximation de l'effet de peuplements d'espèces mixtes. Le long de transects, nous avons évalué le carbone total (C), l'azote (N) et le rapport C/N du sol dans des plantations adjacentes, répliquées et âgées de 12 ans, constituées de *Eucalyptus saligna* (Sm.) pur et de la fixatrice de N₂ *Albizia falcataria* (L.) Fosberg aussi à l'état pur. Les sols du centre des peuplements de *Eucalyptus* avaient plus de C, moins de N et un rapport C/N plus élevé que les sols du centre des peuplements de *Albizia*. Les effets des espèces voisines étaient apparents sur seulement environ 5 m dans les peuplements. Cette distance limitée de l'effet de la parcelle voisine suggère que le rapport d'espèce de 5:1 serait le rapport le plus élevé qui montrerait tout effet des espèces mineures sur ces sols

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Introduction

Tree species clearly influence the development of soil chemistry and fertility (Sanchez et al. 1985; Richter et al. 1994), and the influence of trees differs among species. Replicated species trials have not always supported classic ideas from nonexperimental observations, such as greater nutrient supply in hardwood stands than in conifer stands or relationships between forest floor turnover rates and soil nitrogen (N) supply (e.g., Binkley and Valentine 1991; Gower and Son 1992; Son and Gower 1992; Binkley 1995). Few replicated studies are available on the effects of mixtures

of tree species, but at least one study suggested that mixtures of N-fixing *Alnus rubra* Bong. (red alder) and *Pseudotsuga menziesii* (Mirb.) Franco (Douglas-fir) might have higher P availability than monocultures of either species, demonstrating a large interaction of the two species (Zou et al. 1995).

In the absence of replicated studies that examine a range of species ratios in plantation trials, we thought some insights into the effects of mixtures could be developed by examining the spatial trends of the effects of adjacent plantations. The rate of soil change across stand boundaries may suggest a minimum ratio that a species would have to comprise to substantially affect soil properties of the mixture and whether any species interactions should be expected. In this study, we measured the spatial extent of the influence of N₂-fixing *Albizia falcataria* (L.) Fosberg (= *Paraserianthes falcataria* (L.) Nielsen) and *Eucalyptus saligna* (Sm.) in adjacent stands in Hawaii.

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B. Ewers, D. Binkley,¹ and M. Bashkin. Department of Forest Sciences, Colorado State University, Fort Collins, CO 80523, U.S.A.

¹ Author to whom all correspondence should be addressed.

Methods

The study sites are located near Hakalau on the northeastern coast of Hawaii, at 480 m elevation with a mean annual temperature of 21°C and an average rainfall of 4.6 m/year (Binkley et al. 1992). Slopes are less than 15%, with Typic Hydruand soils of the Akaka series. These soils are deep (>2 m), acidic (pH 4.7 in water), and thixotropic (shrink irreversibly upon oven-drying). The site was cropped with sugar cane for more than 50 years, with the last harvest in 1960. In June 1981, the naturally regenerated vegetation was cleared, the soil plowed, and emerging vegetation sprayed with herbicide. Six species were planted in four replicate blocks as part of a productivity trial by the BioEnergy Development Corporation. Three of the four blocks had randomly located *Eucalyptus* and *Albizia* in adjacent plots. The spacing in the stands was 1.5 × 1.5 m, and the plot size was 14 × 18 m. The plots were fertilized at planting (70 kg N/ha, 32 kg phosphorus (P)/ha, 60 kg potassium (K)/ha) and again at 6 months (40 kg N/ha, 18 kg P/ha, 33 kg K/ha). At age 12 years, the dominant trees were taller than 30 m, with 280 Mg/ha biomass for *Albizia* (mean annual increment 23 Mg·ha⁻¹·year⁻¹) and 350 Mg/ha for *Eucalyptus* (mean annual increment 29 Mg·ha⁻¹·year⁻¹; D. Binkley, unpublished data).

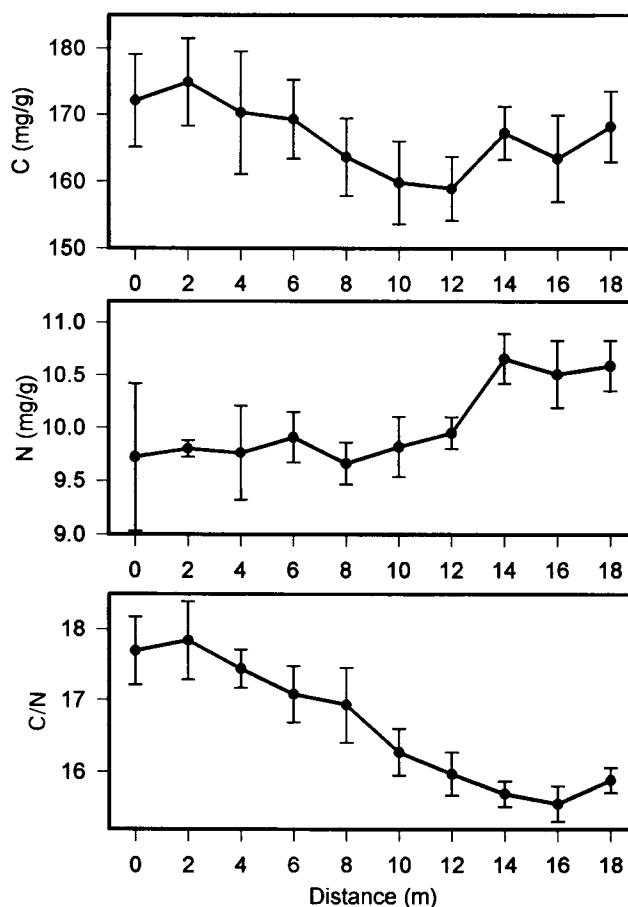
In each adjacent *Albizia* and *Eucalyptus* plot, two parallel transects were located 4 m apart, perpendicular to the stand boundary. The top 0.15 m of mineral soil was sampled every 2 m along each of the 18-m transects, from the center of *Eucalyptus* plots to the center of *Albizia* plots. Five positions were in the *Eucalyptus* stand and five in the *Albizia* stand. Soil samples were sieved through a 2-mm mesh to remove roots and mix the samples and dried at 75°C to a constant weight. Total soil carbon (C) and N were measured by combustion in a LECO-1000 CHN analyzer.

We tested for patterns along the transects using orthogonal contrasts. The 10 sampling positions were divided into 3 groups, with 3 positions on each end, and 4 positions representing the transition zone between stands. Our null hypotheses were that: no difference would be found between the three positions at each end of the transects (testing the effect of the pure species); that no pattern would be found within the three positions at each end (testing for trends within the plots); and that no trend would be found within the four transition positions. We tested these hypotheses with nine orthogonal contrasts: linear and quadratic fits for the contrasts with three points, and linear, quadratic, and cubic fits for the four-point contrasts. Analyses were performed in the MGLH routine of SYSTAT (Wilkinson 1990). We chose to use a *p* value of 0.1 as a balance between the risks of finding significant trends where none existed and concluding no trends existed when in fact they did. However, no *p* values fell between 0.1 and 0.05, so our conclusions would have been the same if we had chosen *p* = 0.05.

Results and discussion

After 12 years of plantation development, the *Eucalyptus* end of transects (positions 1, 2, and 3) had significantly more C (*p* = 0.048 linear, *p* = 0.01 quadratic), significantly less N (*p* < 0.0001 linear, *p* < 0.030 quadratic), and significantly higher C/N (*p* < 0.0001 linear, no significant quadratic) than the *Albizia* end of the transects (positions 8, 9, and 10; Fig. 1). In contrast, no significant patterns were found in total C, N, or C/N within the three sampling points at either end of the transect. Significant effects of the neighboring species on C, N, or C/N were not apparent beyond a distance of 5 m from the border between the

Fig. 1. Trends in C, N, and C/N in 0–0.15 m depth soil, from center of *Eucalyptus* plots (distance 0 m), through the plot boundary (distance 9 m), to the center of the *Albizia* plots (distance 18 m). Error bars are ±1 SE.



stands. No trend was apparent for N within the transition zone (positions 4, 5, 6, and 7), whereas C and C/N exhibited linear declines (*p* = 0.040 linear for C, *p* < 0.0001 linear for C/N; no significant quadratic or cubic) with the transition from *Eucalyptus* to *Albizia*.

The species effects on C, N, and C/N reached only about 5 m beyond the boundary of the plots. Although the plantations were young, we expect that the high productivity and biomass accumulation should have produced a substantial effect of the species, comparable with much longer periods in less productive temperate forests. We speculate that future studies of the effects of tree species on soils might require a buffered zone between plots of only 10 m (5 m of buffer on each side of the boundary), although this may depend on the ability of a soil to buffer the effects of tree species.

Our results also provide some insights into the possible interactions of species in mixed plantations. The C and C/N of the soil responded to the effect of species in the transition zone, suggesting that these properties may be more easily altered in mixed species plantations than soil N would be. Soil N was not significantly greater along the transect until 5 m into the *Albizia* (position 8 and beyond). Beyond 5 m into the plots, the adjacent species had no

significant effect on soil pools of C and N. Given the 1.5-m spacing of the trees, the ratio of species influence at 5 m would be about 5:1 for the main plot : adjacent plot species. We expect that substantial effects of tree species on soils might not develop unless the ratio of major:minor species was 5:1 or less, unless the effect of species on nutrient availability extends further than the effect on total pools. This critical ratio should, of course, vary among sites and species and warrants direct testing.

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