The spatial influence of scattered paddock trees on soil and pasture attributes

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Declaration

I certify that the substance of this thesis has not already been submitted for any degree and is not currently being submitted for any other degree or qualification.

I certify that any help received in preparing this thesis, and all sources used, have been acknowledged in this thesis.

[redacted]

Phoebe M. Barnes

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Abstract

Scattered paddock trees are keystone features in temperate grazing landscapes in Australia. These scattered trees provide a range of ecological functions, and the impact of these trees on the environment is large relative to the small area they individually occupy. However, our understanding of the influence of these trees on their immediate environment is limited. In this thesis, the effects of scattered mature *Eucalyptus* trees on both native and sown pasture systems are examined in the temperate landscapes of the Northern Tablelands of New South Wales, Australia. Specifically, the influence of scattered trees on soil fertility, litter distribution, the nutrient pools in litter, pasture production and nutrient status, as well as the root distribution of a mature tree and the influence of shade on pasture biomass, are observed.

The coarse tree roots (≥10 mm) of a scattered tree decreased with increasing depth in the soil and distance from the tree, forming a broad inverted conical structure. Most roots were largely restricted to within 2 canopy radii of the tree, and 80% of coarse roots were found below 20 cm in the soil profile. This suggests that coarse tree roots and pasture roots are unlikely to compete for the same soil resources because they occur largely at separate depths in the soil profile.

Scattered trees are associated with a distinct and systematic horizontal and vertical change in soil attributes in the upper 0–75 cm of soil although the magnitude, intensity and pattern of these effects differed according to the soil attribute in question. Scattered trees were associated with an increase in soil fertility out to approximately 2.5 canopy radii, with no indication that the increase came at the expense of surface soil nutrients beyond the canopy edge. Soil pH_{Ca} at seven different locations was acidic from the tree trunk, but exhibited individualistic patterns of variation with depth among locations, and varied little among concentric zones around trees. When averaged over the top 75 cm of the soil profile, total soil C was higher by 25–185% under the tree canopy than in the open paddock (i.e. the zone extending 10 m beyond 2.5 canopy radii from the tree trunk), as was total N (25–230%) and total S (0–60%), and for the most part available P (–10–340%) and EC (–13–180%). Often soil fertility in the transitional zone (between the canopy edge and the open paddock) was intermediate between the under canopy zones and the open. Soil C, N, S, available P and EC generally declined exponentially from the soil surface, with the largest magnitude of change occurring in the top 10 or 20 cm of the soil profile. As most

coarse tree roots were found below this depth, these results are most likely due to nutrient cycling caused by tree litter addition at the soil surface. This study not only added to the growing literature on the positive influence of scattered trees on soil fertility, but established that scattered trees have tangible value in grazed temperate landscapes in terms of increasing topsoil fertility.

Eucalypt litterfall decreased with distance from the tree stem. However, due to the larger area, a large quantity (36–75%) of litter accumulated beyond the canopy edge. Between 54 and 145 kg of tree litter was found on the soil surface around individual trees and an average of 181 kg of litter accumulated around each tree over the course of a year. Similar quantities of each nutrient were deposited in tree litter in each season. There were few seasonal differences in nutrient concentration in any litter component. The spatial patterns of litter distribution around scattered trees coincided with spatial patterns in soil properties found in this study and elsewhere. For example, there was a strong correlation between the density (g/m^2) of C contained in litter in different concentric zones around trees and the density (kg/m^2) of soil C in the top 5 cm of the soil profile (r^2 typically ranged from 0.6–0.9). The location and concentration of the litterfall and its decomposition, is likely to at least partly explain the spatial patterns in soil fertility associated with scattered trees. This suggests that the loss of scattered trees from pastoral landscapes in temperate NSW will result in the loss of significant litter and nutrient inputs.

Around the scattered trees in this study, ungrazed green dry biomass (GDB) of pasture was larger under or near scattered trees compared to the open paddock in summer–autumn. Similarly, GDB consumption by cattle was larger under or near scattered trees compared to the open paddock in summer–autumn. Consequently, the GDB remaining in the paddock after grazing was often significantly smaller under or near scattered trees compared to the open paddock. When biomass in grazed paddocks was examined in multiple locations, no difference in the total GDB was found with increasing distance from scattered trees. However, variation in the percentage GDB of total biomass was common, especially in native pastures, with the percentage GDB being larger under scattered trees than in the open paddock. Using an active-optical-sensor, the Normalised Difference Vegetation Index (NDVI) of pasture was observed around scattered trees. The relationship between NDVI and GDB was significant but weak (best $r^2 = 0.42$). The low r^2 values were probably due to senescent pasture masking the GDB from the sensor in native pasture and index saturation in sown pastures. A consistent directional trend was evident, with larger GDB on the southern side of trees and lower GDB on the northern side in native pastures in the region. Trees may enhance pasture biomass to the south, compensating for a reduction in biomass on the northern side of the tree. However, as direction was not accounted for in the biomass measurements in this study more work is required to qualify this assumption. Pasture nutrient concentrations (Ca, P, K and S) were often higher under the tree canopy compared with the open paddock, and this trend occurred in both native and sown pastures. Overall, it was concluded that scattered trees facilitated pasture growth in summer–autumn, and were associated with higher pasture nutrient concentrations.

The higher NDVI on the southern side of trees suggested that pasture biomass was enhanced by shade of the trees. Consequently, in a controlled field experiment, the role of shade in influencing pasture NDVI (and pasture biomass) was investigated. The effects of varying levels of shade (afternoon shade only, morning shade only, full shade and no shade) on above-ground grass biomass, NDVI and soil temperature and moisture were studied over the course of 32 weeks from summer to winter, simultaneously monitoring inflorescence development. Three grass species with different photosynthetic pathways and light tolerances, *Microlaena stipoides* (C_3, shade tolerant), *Austrodanthonia richardsonii* (C_3, preferring full sunlight) and *Chloris ventricosa* (C_4, preferring full sunlight) were examined. Shade had little influence on plant biomass of C_3 species, but shade significantly reduced biomass of the C_4 species. Until early winter, the NDVI of each species was generally significantly higher in all shade treatments than in the unshaded treatment, implying that a higher percentage of green biomass occurred in the shade. This may have been due to plants in the shade (a) retaining a higher proportion of green biomass or (b) changing leaf shape, increasing leaf area and chlorophyll content. Whatever the causal factor, shade prolonged the retention of green plant material until mid–late winter. The C_3 grasses, being year-long green perennials, varied little in NDVI throughout the experiment but the NDVI of the C4 grass (a warm-season perennial) declined significantly after mid autumn. This experiment explains the directional trends in NDVI found in previous work, and suggests that shade from scattered trees would be beneficial to landholders in this temperate region for green pasture production in a range of native grass species.

Overall, the results of this thesis are relevant for landholders and natural resource managers in grazed temperate landscapes because they enable more informed decisions about the retention or re-introduction of scattered trees in these ecosystems. Furthermore, the work demonstrates that the value of scattered trees is not limited to stock shelter and aesthetics, but that trees are beneficial for their immediate soil and pasture surroundings. As a result, landholders, natural resource managers and policy decision makers should be encouraged to acknowledge the important and valuable ecosystem functions (ecosystem services) of this declining resource to the agricultural sector.

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