Tillers 2002, **3**, 1-4

Quercus macrocarpa has no significant effect on surrounding soil in restored savannas

ANDREW AUSTIN-PETERSEN, NATALIE LARSON, and DARRYL NEUFELD
Biology Department, Grinnell College, Grinnell, IA 50112, USA

Abstract

Trees can alter their surrounding soil drastically enough to create niches which favor flora that would otherwise find an area inhospitable. This study examines the effects of Quercus macrocarpa *(Burr Oak) trees on their surrounding soil. In late fall on the Burr Oak Savanna at the Conard Environmental Research Area, ten trees were studied for their effects on soil moisture, carbon content, temperature, strength, pH, and nitrogen levels. Though results were insignificant, averages indicated that soil inside the canopy has higher carbon levels, pH levels, and nitrogen content than soil outside, while soil outside has higher moisture, strength, and temperature levels than soil inside. Possible reasons for the nonsignificant difference are time of the year, individual tree species, size and age, and proximity to other trees.*

Introduction

As the global economy continues to demand increased crop production, the agriculture industry continues to demand more land on which to grow crops (National Resources Inventory 1997 data on land use in the United States). One way to increase cropland efficiency (and thereby reduce land used to grow crops) is to employ agroforestry, a process in which particular trees are planted near crops in order to influence soil characteristics which benefit the crops, thus creating a higher yield (described in Young 1988). If more agroforestry is employed, land otherwise used for crops could be used for preservation purposes.

Specific trees have specific effects on the soils they inhabit. Trees can thus be used to replenish the soil with nutrients needed to create specific biomes otherwise lost to the nutrient-depleting effects of industrial agriculture (Boettcher and Kalisz 1990, Young 1988). Understanding the effects of trees on their surrounding soil helps find a solution to the dilemma of equitable land use between agriculture and conservation, and assists restoration efforts by helping create appropriate conditions for the desired biomes.

Many gradients of tree influence on soil have been explored: Ko and Reich, in their 1993 study of the effects of oak trees on soil and herbaceous vegetation in savannas and pastures, found that because light intensity increased with distance from a tree's trunk, soil temperature did also. Studying the effects of climate change on decomposition processes in grasslands and coniferous forests, Andersen (1991) found that as decomposition rates are a function of temperature, the rate of decomposition should increase with distance from the tree's trunk. Because increased decomposition rates cause carbon to be more quickly recycled back to the atmosphere, the carbon content of the soil should decrease as the distance from the tree's trunk increases. Ahmad-Shah and Reiley, in their research concerning the effects of rainwater passed through tree canopies onto the soil below (1989), found that soil moisture decreased with increased distance from the tree's trunk, due to higher levels of leaf litter and therefore lower levels of evaporation under the canopy. Consequently, soil strength increased with distance from a tree's trunk. Zinke, in his 1962 investigation of the patterns of influence of individual forest trees on soil properties, determined the pH of surrounding soil to increase with increased distance from the tree's trunk due to the more acidic nature of tree bark and more basic nature of tree leaves. Zinke (1962) also found soil nitrogen content increased with increased distance from the trunk due to the high nitrogen content of tree leaves.

Knowing that soil effects the flora it maintains, (Ko and Reich 1993) we chose to examine *Quercus macrocarpa* trees on the Burr Oak Savanna in the Conard Environmental Research Area for their impacts on moisture, temperature, pH, carbon content, nitrogen content, and strength of their surrounding soil with respect to the gradient of proximity.

Methods

On Monday, October 28, at ten relatively isolated *Quercus macrocarpa* (Burr Oak) trees, we used a 2cm diameter soil core sampler to take 10cm deep cores at 6 points: one point in one randomly chosen direction halfway to the canopy edge (50%), one at the canopy edge in the same direction (100%), and one at one and one half times the distance from the tree trunk to the canopy edge (150%). The other three points we took in the opposite direction at the same proportions relative to that side's canopy edge. We examined these three distances in order to determine whether there was a discernible gradient moving out from the trunk. On Wednesday, November 6, we took two 10cm core samples from all ten trees at the previously marked 50% and 150% points. We combined the samples having the same radius from a given tree, and sent these samples to be tested for nitrogen content.

In addition to taking soil cores, at each point a penetrometer was used to determine soil strength. We measured the circumference of the base of each tree and noted characteristics about the proximate landscape (e.g. hills, streams, etc.); four trees were sampled on that Monday, the remaining six two days later. On the second day, we also used a digital soil thermometer to determine soil temperature at a depth of 4cm for six of the original 10 trees.

We calculated moisture content by weighing all soil samples prior to and after drying them in an oven at 60 degrees Celsius for four days. We used 10 grams of dried soil for the solid component of a 1:4 aqueous solution and used an Oakton pH Testr2 to determine pH levels. Additionally, we sieved and weighed the remaining dry soil from each sample, burned the soil at 400 degrees Celsius for 1 hour, then weighed the soil again to determine carbon content.

Data were analyzed for significance using a t-test assuming both equal and unequal variance.

Results

While our data typically suggested that trees did affect the surrounding soil, no differences were statistically significant. The soil from Oct. 28 showed on average that soil moisture was higher at 150% of the canopy distance than at 50% (t=2.07, p= .66), while the soil from 2 days later actually showed opposite results (t=2.14, p=.48) (Figure 1) with the lowest levels at the edge. Mean carbon levels were higher under the canopy than outside, and levels were lowest at the canopy edge, (t=2.02, p=.21 between the under and outside the canopy) (Figure 2). Soil temperature was on average higher outside the canopy than under (t=2.14, p=.23) (Figure 3). Mean soil strength was higher outside the canopy than under the canopy, but was highest at the canopy edge (t=2.02, p=.41 between under and outside the canopy edge) (Figure 4). Soil pH (Figure 5) and total nitrogen levels (Figure 6) were higher under the canopy than outside (t=2.02, p=.17, t=2.10, p=.50) (Figures 5, 6).

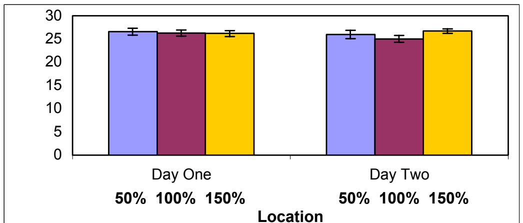

Figure 1: Soil Moisture (+/- Standard Error)

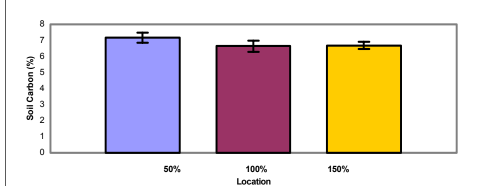

Figure 2: Mean Soil Carbon (+/- Standard Error)

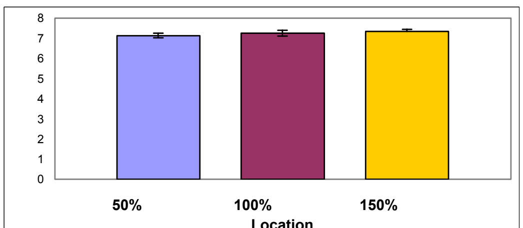

Figure 3: Mean Soil Temperature (+/- Standard Error)

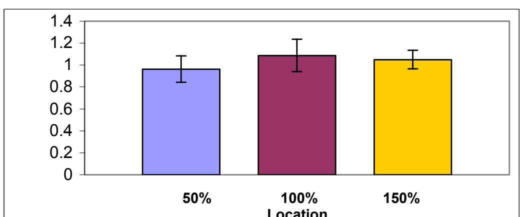

Figure 4: Soil Strength (+/- Standard Error)

Additionally, we separated and compared the data between trees greater and less than 1.5m in circumference. We found that average total nitrogen and carbon levels for these trees were higher under the canopy than outside (t=2.23, p=.41, t=2.10, p=.54 respectively, data not shown). For small trees, both nitrogen and carbon levels were higher under the canopy than outside (t=2.45, p=.91, t=2.14, p=.24, respectively, data not shown.)

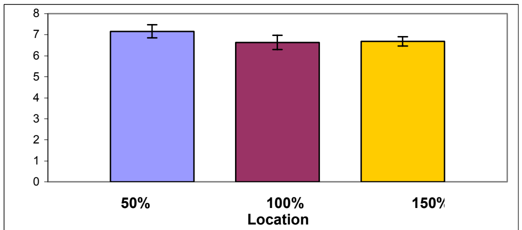

Figure 5: Mean Soil Carbon (+/- Standard Error

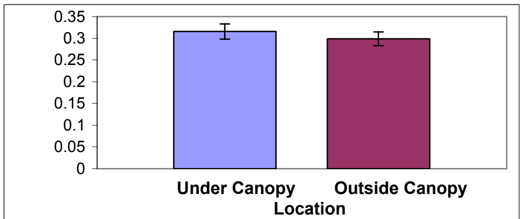

Figure 6: Total Nitrogen Soil Content (+/- Standard Error)

Discussion

Though the data indicate that Burr Oak Trees do not have a significant effect on the surrounding soils, the trends in soil temperature, pH, nitrogen, and moisture content suggest that trees do influence the surrounding soil. Here we examine the possibilities that may have decreased the consistency of trends.

First, all the trees in our study were on varying gradients. Topography could have affected the results by causing moisture and possibly nutrients to move downhill–either toward or away from the tree trunk. However, Boettcher and Kalisz (1990) in a study conducted in the mountains of Kentucky, found that slope did not affect the soil nutrient gradient from under to outside tree canopies.

Another factor that could have affected the results was time of year. Our study was conducted in mid-autumn, which may have eliminated any difference in soil moisture. At the time of the study, there were few leaves remaining on trees. Ahmad-Shah and Reiley (1989) found that the extra shade provided by the foliage lowered the evaporation rates, therefore increasing the under-canopy soil moisture and decreasing the strength. Had we performed our study during the summer months, there would have been more foliage in the canopies, which would more drastically affect these factors, causing more distinct differences between under and outside the canopy.

Tree age may be another factor—in a study measuring the effects of trees and their effects on specific flora, Gehrig and Bragg (1992) found that certain plant species did not respond to the impacts of the trees until the trees reached a particular age. Furthermore, Ahmed-Shah and Reiley (1989) found that throughfall effects depended greatly on the ages of the trees. Similarly, our analysis indicates that larger trees have more of an effect on the factors we studied (though these trends were not significant.) Perhaps had we been able to study only older trees, the differences would be more apparent.

The trees available for study at CERA were not completely isolated. We attempted to locate Burr Oaks free from neighboring trees on all sides, though there were few that adequately fit this profile; what was outside one tree's canopy was sometimes under another's. Therefore, some comparisons may actually have been between the impacts of two trees instead of one tree and no tree.

A marked difference in the composition of above ground flora was noted during sampling, where substantially less big bluestem was noted. Parker and Miller (1982) found that the effect trees have on soil directly affects the surrounding flora. This suggests that there is a difference in the environment under versus outside canopies. The difference, however, could be related to light levels, the amount and composition of throughfall (the water reaching the ground through the canopy), or soil temperature during the warmer months of the year, none of which we studied. Boettcher and Kalisz (1990) also noted that tree species greatly affects the influence an individual has on soil nutrient content.

We propose a further correlative study which examines solely isolated, old trees, and includes light intensity and throughfall analysis. Furthermore, we suggest the study be conducted earlier in the year, when the trees have more leaves, and therefore have more of an influence on light intensity, throughfall, and moisture.

Acknowledgments

Thank you:

Professor J. Brown for his assistance in the design of our experiment, providing insights into possible additional research, and providing assistance on our methodology, not to mention safely driving us to and from CERA a number of times.

Larissa Mottl for providing us with the tools and resources to conduct our study, the permission to foolishly trample precious plants at CERA, and providing further articles for our research.

Sue Kolbe for helping us in the lab with tools, instruments, and directions, and for tolerating our messes.

Georgia Hart for assistance in ideas, methods, and moral support

Literature Cited

Ahmad-Shah A. and J. O. Reiley. 1989. Influence of tree canopies on the quantity of water and amount of chemical elements reaching the peat surface of a basin mire in the midlands of England. *Journal of Ecology*. **77:**357-370.

Anderson, J.M. 1991. The Effects of Climate Change on Decomposition Processes in Grassland and Coniferous Forests. *Ecological Applications*. **1:** 326-347

Gehing J. L. and T. B. Bragg. 1992. Changes in prairie vegetation under eastern red cedar (Juniperus virginiana L.) in an eastern Nebraska bluestem prairie. *The American Midland Naturalist*. **128:**209-217.

Ko L.J. 1993. Oak tree effects on soil and herbaceous vegetation in savannas and pastures in Wisconsin. *American Midland Naturalist.* **130:**31-42.

National Resources Inventory1997 www.nrcs.usda.gov/technical/NRI/1997/summary_report/table5.html

S. E. Boettcher and P. J. Kalisz. 1990. Single-tree influence on soil properties in the mountains of eastern Kentucky. *Ecology*. **71**:1365-1372.

V.T. Parker and C.H. Muller. 1982. The Vegetational and Environmental Changes Beneath Isolated Live Oak Trees (Quercus agrifolia) in California Annual Grassland. *American Midland Naturalist*. **107:** 69-81.

Young, Anthony. 1988. Agroforestry and Its Potential to Contribute to Land Development in the Tropics (in The Humid Tropical Environment and Development). *Journal of Biogeography*. **15:**19-30.

Zinke, P.J. (1962) The pattern of influence of individual forest trees on soil properties. Ecology **43:** 130-133.