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Variable effects of tree-cover on plant productivity and diversity of forbs and shrubs

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Abstract

In an effort to understand the effect of trees upon plant productivity, and species diversity and richness, all were observed at both the savanna and tree line at Conard Environmental Research Area (CERA). Biomass and necromass (an indicator of plant productivity), species diversity and richness of shrub and forb samples were taken at the savanna with the use of transects from the center of trees. Then we sampled along these transects at 2m(under the canopy) and 10m(outside the canopy) from the base of each of the eight trees. At the tree line, 18 samples were taken from both the forest and the prairie side. The results of biomass and necromass sampling yielded no significant relationship with the proximity of trees. There is a significant difference in species diversity and richness at the tree line; however there is no significant difference at the savanna. Thus, plant productivity has no significant relationship dependent upon the vicinity of trees, but tree cover can affect species diversity and richness.

Introduction

The savanna, a common ecological community in pre-settlement times in the Midwest, consists of an understory of grasses and forbs below scattered trees or groves (Ladd 1995; Nuzzo 1985). In Iowa specifically, the history of the extent of savannas is questionable since people only recorded land as either prairie or forest and rarely directly referred to open woodland spaces as savanna. Tree invasion into prairie also creates difficulty in determining the original environment (Nuzzo 1985).

Information about the effects of trees on their environment will be beneficial in restoring diversity among prairies, savannas, or forests when choosing what species to seed . Knowing the effects of tree cover on plant species can reveal which plants are more nutrient or photosynthetically adapted than those out in the open, and also how plant composition will change depending upon environment.

In a study about species composition of prairies and savannas in old settler cemeteries, Betz and Lamp (1993) concluded that savannas have less species richness and diversity than the open prairie. Although they did not address the causes of these differences, diversity may be affected by the altered soil conditions and light levels influenced by trees (Ahmad-Shah and Rieley, 1989). Biomass and necromass may be affected by these soil conditions and light levels. Under a canopy, light levels and the quality of the light spectrum or energy distribution is decreased (Shirley, 1929). Since photosynthetic rates are proportional to growth, there should be more biomass away from canopy cover. Also, decomposition rates will be higher (less necromass) away from canopy due to the increase in sunlight heating the ground (Falconer et al; 1932).

Through our study we hope to clarify some of the impacts that trees have upon ground vegetation by studying plant productivity (biomass and necromass), species diversity and richness. We hypothesize that trees will cause a decrease in the diversity and richness of forbs and shrubs, while causing a decrease in biomass and an increase in necromass due to the lower light levels.

Methods

We took our data at Conard Environmental Research Area (CERA) between October14th and November 18th 2002. Data was first collected from the annually burned Oak savanna, which is still in the process of restoration from its previous state as an ungrazed pasture. We also collected data from both the Oak/Hickory forest and the adjacent Morgan prairie. The Oak/Hickory forest was logged until the 1860s and now consists of Oak, Hickory, Ironwood, and Basswood trees, in addition to forbs and woodland grasses. The Morgan prairie is a flat area with several ten-year-old experimental oak trees interspersed throughout.

Savanna

We selected eight bur oak trees, which were isolated from the canopy of surrounding trees in order to avoid any influence from neighboring trees. At each tree we randomly selected three different degree angles from which we marked points at 2 and 10 meters from the base of the tree. At each point we collected biomass and necromass samples and measured the forb and shrub diversity and richness. We neglected measuring the diversity and richness for grasses because of time limitations. We collected all our biomass and necromass samples from the savanna and forest line between October 14th and November 6th. We took all biomass and necromass samples before measuring the species diversity and richness in order to avoid the effects of the seasonal changes in temperature that would hinder us from distinguishing between biomass and necromass. We measured biomass and necromass from .25x.25m quadrants. Samples were dried at 60 degrees Celsius and weighed. After weighing, we used a t-test to find differences between under and outside the canopy.

On November 6th, we returned to the same trees and measured diversity for forb and shrub species, in .5x.5m quadrants placed adjacent to the already sampled locations. We used a paired t-test to look for differences between both species diversity (Simpson's index) and richness.

Forest Line

In the Oak/Hickory forest we marked off a 30x30m plot, in which the middle 10x30m horizontal segment along the tree line served as a buffer zone from which no samples were taken. This variable zone was excluded in an effort to get data from each extreme; we wanted to see a distinct difference between the prairie and the forest. These zones were divided into three 10x10m replicates. From each plot, we randomly sampled six points for biomass/necromass and then measured forb and shrub diversity and richness, using the same sampling methods as in the savanna.

Results

Savanna

We found no direct effect of trees on plant productivity, and species diversity and richness. The mean biomass 10m away from the base of the tree was 4.7% greater than the mean biomass 2m away, but this difference was not significant (t=.113, p=.91). On the other hand, the mean necromass at 2m was 31% larger than at 10m; however, this difference was also not significant (t=2.11, p=.053)(Fig. 1).

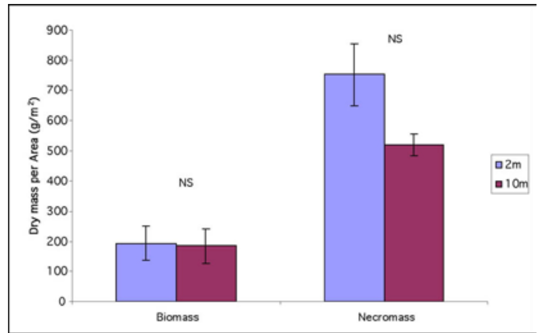

Figure 1: Mean biomass/necromass of a m^2 plot at 2m and 10m distances from trees in the savanna (+/- Standard Error).

We observed many of the same species across the different sample sites. The most common species we encountered were: *Chamaecrista fasciculata*, *Rosa multiflora*, *Solidago canadensis*, *Daucus carota*, *Echinacea purpurea*, and *Ratibida pinnata*. The species richness in the savanna at 2m from the tree was lower than at 10 m, but a t-test reveals that this difference is not significant (t=.275, p=.784)(Fig. 2). Although there was slightly more diversity at 10m (2.15 vs. 2.14), it was also not significant (t=.063, p=.95)(Fig. 3).

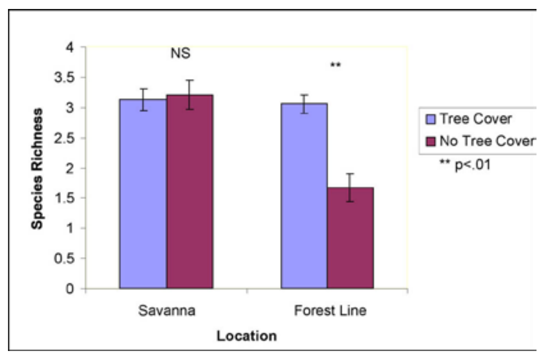

Figure 2: Species richness of a .25x.25m plot under and away from tree cover (+/- Standard Error).

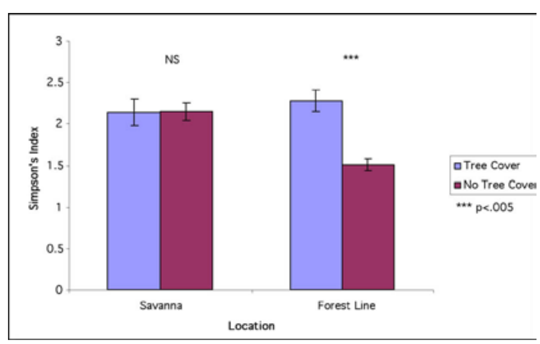

Figure 3: Mean diversity of forbs and shrubs under and away from trees in the savanna and forest line (+/- Standard Error).

Tree line

Prairie areas had non-significantly greater (2.62% greater) biomass than forest (t=.05, p=.96). Necromass was also greater in the prairie (48% greater), but was not significantly different (t=2.46, p=.07)(Fig. 4).

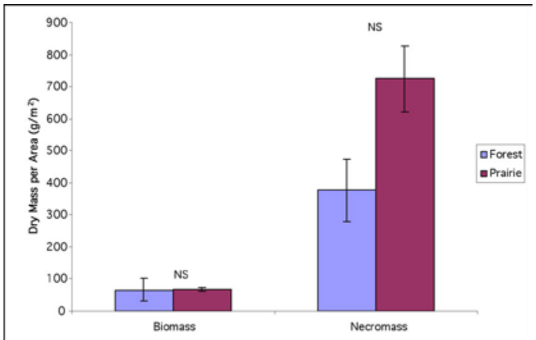

Figure 4: Mean biomass/necromass of a m^2 plot under and away from trees at the forest line (+/- Standard Error).

Species richness in the forest was significantly higher than in the prairie (t=5.07,p=1.39E-6) (Fig. 2). The forest also had significantly greater diversity (2.3 vs. 1.5) than the prairie (t=5.0, p=.0075)(Fig. 3).

Discussion

Our study revealed that tree cover had no direct effect on plant productivity, yet had variable effects upon species diversity and richness.

Plant Productivity

Though our data on plant productivity via biomass and necromass measurements yielded statistically non-significant mean differences, there were still some trends. These non-significant differences may be due to the fact that our data was extremely dependent upon many variables, including temperature, season, soil moisture, nutrient levels, and light intensity.

As the course of our study progressed, the fall temperatures neared the lower portion on a range from 80 to 20 degrees Fahrenheit, causing plants to die. In addition to fall bringing lower temperatures, the hours of daylight are less, and therefore, decrease the energy intake of plants through photosynthesis, causing them to die. These seasonal factors possibly caused our inconclusive data because they drastically decreased biomass measurements, and increased necromass collection.

One trend that was reflected in the data was an increase in biomass away from the canopy of trees. According to a different study conducted at CERA in the same Oak Savanna from which we sampled, *Querus macrocarpa* trees lead to an increase in carbon and nitrogen levels under the canopy (Austin-Petersen et al, 2002). Although this was statistically not significant, these trends lead us to believe that higher nitrogen levels are not the limiting factor promoting growth and increased biomass. This suggests that other variables, such as sunlight, may be the limiting factor causing decreased biomass under the canopy. Ko and Reich (1993) conducted a very similar study, in Dane County, Wisconsin on restored oak savannas, focusing on how species composition, ground cover and biomass vary underneath tree canopies and open areas. They found greater biomass away from the canopy cover, which they attribute to sunlight and/or allelopathic chemicals from oak litter, despite there being seemingly favorable conditions under trees with higher moisture and nutrients (Ko & Reich, 1993). Allelopathic chemicals, which are a result of the decomposition of tree matter, can inhibit growth of vegetation (Heisey, 1990).

Necromass data from the savanna conflicts with our data from the forest line. At the savanna, necromass is greater under the canopy, while at the forest line necromass is greater in the open prairie. According to Ko & Reich (1993), necromass in savannas is greater than in open prairie, which complements our savanna trends. Soil moisture increases with forest tree cover, and soil moisture is a limiting factor in the decomposition of necromass (Ahmand-Shad and Reiley, 1989; Falconer et al, 1932), which could explain why we found less necromass under the forest canopy than in the drier prairie.

Species Richness and Diversity

The species diversity and richness under and away from trees at the savanna conflicts with the data of species diversity and richness under and away from trees at the forest line. Though not statistically significant, the trend at the savanna suggests higher diversity away from the canopy. This non-significance may be due to a history of seeding, in which the trees in the savanna may not have had enough time to impact the species diversity and richness or the seed placement was not uniform. The trend we found is supported by a study that measured higher plant diversity in open prairie versus savanna (Ko and Reich 1993). It is important to acknowledge that Ko and Reich also measured grasses in addition to forbs and shrubs because it is more representative of the environment. Our forest site showed the opposite trend, though this time the mean difference was significant, where canopy cover increases species diversity and richness. Halpern and Spies (1995) found similar results comparing with forests and open prairies in the Pacific Northwest. This shows that trees don't have a consistent affect on species diversity and richness. Rather the impact that trees have on species diversity and richness is dependent upon the different ecosystems such as the savanna or forest.

Conclusions

In order to better understand the relationship between tree cover and plant productivity, species diversity and species richness, the many variable factors that we encountered in our study need to be observed. Some specific factors that would help confirm a relationship would be monitoring soil moisture, soil temperature, nutrient levels and light intensity levels. In continuing this study, one should consider the season in which observations of plants, soil and sunlight are made, preferably during late July or August after plants have had an opportunity to establish themselves.

The results of our study, though not conclusive in many of its components, can now be used to understand the effects of trees on vegetation, and be applied to the seeding processes during restoration of open prairie, savanna and forest. In a future long-term study, it would be beneficial to seed species that are common in all the ecosystems observed, under and away from the canopy, to determine whether sunlight is the limiting factor for plant productivity and to see how plant diversity changes with time. Hopefully past studies, this study and those in the future relating to the effects of trees on vegetation, will help the restoration of these unique wooded ecosystems.

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