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Biomass and Burn Cycles in a Tallgrass Prairie of Southern Minnesota

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BIOMASS AND BURN CYCLES IN A TALLGRASS PRAIRIE OF SOUTHERN MINNESOTA

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Abstract

The biomasses of four sections of tallgrass prairie in southern MN, USA, were examined to determine the effectiveness of the burn regime. Each section was last burned in a different year, 2010, 2012, 2013 and 2014. At each location, the biomass of forbs and grasses was taken separately to determine if there was a difference in biomass between the four sections. Soil was also collected to determine percent moisture and percent organic matter. The section last burned in 2013 had the greatest biomass of grasses, at 606.4 g/m^2, while the section burned in 2012 had the smallest biomass of grasses, at 98.4 g/m^2. Alternatively, the section burned in 2010 had the greatest biomass of forbs, with 246.4 g/m^2, while the section burned in 2014 had the smallest biomass of forbs, with 11.2 g/m^2. The section burned in 2013 had the greatest total biomass while the section burned in 2012 had the smallest total biomass. While none of the results were statistically significant, the biomass of forbs generally decreased as years since the last burn decreased. The percent organic matter also tended to decrease as years since a burn decreased, while the percent moisture tended to increase. Over time since a burn, it appears that grasses, which initially dominate, are then replaced by forbs, perhaps due to the higher amount of organic matter in the soil or because they are more resistant to the lower amount of moisture. It is expected that the sections will continue this trend, and in three years, the section burned in 2014 will be dominated by forbs. The lack of a clear plateau in the amount of forb cover suggests that a four-year burn cycle is not too short.

Introduction

Tallgrass prairie used to cover the Midwest. However, once settlers recognized the fertile soil, they began to change the prairie into agricultural land. Now, the area that was once prairie has declined by between 88 and 90 percent (Reinking 2006). The decline in grassland has in turn caused a decline in the number of species that use the grassland for food and shelter. Grassland bird species have declined more rapidly than any other bird species due to the decline in grasslands (Sampson and Knopf 1994).

Prairies that remain are often used for cattle. The introduction of livestock has caused the frequency of fire to decline due to a lack of fuel, which alters the composition of the prairie by allowing plant species to thrive that would otherwise be eliminated by fire

(Brockway *et al.* 2002). While the decline of prairies has a severe impact on the survival of animal species, changes in the composition of the prairie can also have a negative impact.

Recently, efforts have been made to restore the prairie within its native range. St. Olaf College has converted over 150 acres of land, once used to grow corn and soybeans, into restored prairie.

To better imitate the conditions of the original prairie, natural disturbances are necessary to help maintain the grassland. An important natural disturbance is the presence of fire (Collins and Wallace 1990). Fire benefits tallgrass prairies by creating a mosaic of habitats based on when the fire occurred. As the amount of time since a burn increases, the cover of grasses decreases and the cover of forbs increases (Gibson, D. J. and L. C. Hulbert 1987). These different habitats increase the plant biodiversity of the prairie by encouraging the growth of grasses in some locations and the growth of forbs in others. It also enables biodiversity in the number of animal species by creating more niches that animals can fill (Risser 1988).

When restoring a prairie, it is important to understand the effect that burning has on the prairie, and to find a balance in how often a prairie should be burned. While biodiversity of plants increases as years since a burn increases, there is a point when the biodiversity begins to decrease (Collins and Wallace 1990).

To assess the current burn regime on portions of the St. Olaf College Natural Lands, I looked at the biomass of grasses and forbs in sections of St. Olaf's restored prairie. Using these data, I looked at the succession that occurs on the St. Olaf College Natural Lands. Since forbs provide most of the plant biodiversity in a prairie, looking at the trend of forb cover in different prairie sections will help us make better estimates of how often a restored prairie should be burned (Collins and Wallace 1990).

I tested the hypothesis that biomass of forbs on the St. Olaf prairie will increase with years since a burn while biomass of grasses will decrease with years since a burn. If this hypothesis turns out to be true, then the rate of increase of the biomass of forbs as time since a burn increases can be observed. If the amount of biomass of forbs plateaus, it might suggest that a point has been reached where biodiversity will no longer increase, at which point a burn would be necessary. If no plateau of the biomass of forbs is found, then it suggests that the current burn regime of burning on a four year cycle should either be continued or is occurring too frequently.

Methods

Sites

All of the sites used are part of the St. Olaf College Natural Lands, located in Northfield, Minnesota. I chose four sections of the Natural Lands burned in different years (2010, 2012, 2013, and 2014). The 2010 section was comprised of two sections restored in different years, one in spring 1998 and one in fall 2002. The 2012 site was restored in fall 2001, the 2013 site was restored in spring 1993, and the 2014 site was restored in spring 2002. There were no sites where the last burn occurred in 2011. Of the sites sampled, the section burned in 2012 has the smallest area. The section burned in 2014 is next, followed by the section burned in 2013 and the section burned in 2010. The exact areas for these sections are unknown.

Plant Collection

I took two .5m x .5m plots in each section, resulting in a total of eight plots sampled. To determine the location of a plot within a section, I randomly chose a spot on the path outside of that section and walked forward for 40 paces Within a plot, I cut all of the plants a few centimeters above the ground and placed them in brown paper bags.

Soil Collection

I used a soil corer to get an exact volume of soil, which was then stored in pre-weighed metal tins. I took two samples from each section, for a total of eight samples. I initially tried to collect soil samples from the same plots as the plant cuttings, but some samples were taken from different locations because they were collected at a later time.

Biomass Analysis

Biomass is the dry weight of the plants. For each section, I combined the two plots and then split the plants into grasses and forbs. I used an electronic scale to mass each plant group from each section, placed them into separate paper bags, and placed them in a Precision™ oven for 48 hours. I then massed the plants a second time to determine the biomass of the grasses and forbs in each section.

Soil Analysis

I pre-weighed the tins used for soil collection. After they were filled, I massed the filled tins to calculate the original mass of the soil, then placed them in an oven set at 105°C for 24 hours to let them dry. After drying, I massed the filled tins again. I used the following equation to determine the percent moisture of the soil:

$$\text{Percent moisture} = \frac{\text{weight of water}}{\text{dry weight of soil}} \times 100$$

Next, I ground the dried soil in a mortar and pestle, and ran it through a 2mm sieve. I measured between 4.5 and 9 grams of the pulverized soil into a metal weigh boat and placed it into a second oven set at 500°C for 4 hours. I then massed the tins, and used the following formula to determine the percent organic matter:

$$\%\ \text{organic material} = \frac{(\text{weight after 105 C- weight after 500 C})}{\text{weight after 105 C.}}$$

Methods were taken from Field and Laboratory Methods for General Ecology (1997).

Data Analysis

I used a one-way analysis of variance to evaluate the means for percent moisture, percent organic matter, and total biomass. I used a correlation test to compare the percentages of the biomass composed of forbs and of grasses for each section, to the percent moisture and percent organic matter for each section. I used the R statistical program to run all statistics.

Results

Biomass of Grasses and Forbs

Total biomass was fairly similar across all burn sections, with the exception of the 2012 section (Table 1). There was no significant difference between the means of the total biomass for each section (Table 3), indicating that no conclusions can be drawn about the effect of years since a burn on total biomass.

In general, as time since a burn increased, the biomass of grasses decreased. The biomasses of grasses in 2013 and 2014 were very similar, although the biomass in 2013 was slightly higher. Both sections contained substantially more biomass from grass, than did the 2010 section (Table 1). When the biomass of grass is converted to a percent of the total biomass for each section, there is a consistent decrease in the percentage of grasses present as years since the burn increased, with the exception of the 2012 section. Of the four sections sampled, it had the lowest percent biomass made up of grasses (Table 2). The biomass of grasses in each section does not appear to be correlated with the percent moisture or the percent organic matter found in the soil (Figures 1 and 2).

Forbs showed the opposite trend. As years since a burn increased, the biomass of forbs increased for all sections (Table 1). However, when the biomass of forbs is changed into percent of the total biomass for each section, the section burned in 2012 has the highest percent of the biomass made up of forbs (Table 2). In addition, the biomass of forbs in each section does not appear to be correlated with the percent moisture or the percent organic matter found in the soil (Figures 3 and 4). As the biomass of forbs increase, the biomass of grasses decreases.

Percent moisture and percent organic matter

The mean for percent moisture for each of the four sections was not found to be significant, indicating that there was not enough of a difference between the percent moisture in the soil to draw conclusions about how years since a burn affects percent moisture (Table 4). Similarly, the mean for percent organic matter for each of the four sections was not found to be significant, indicating that no conclusions can be drawn about how years since a burn might affect percent organic matter (Table 5). While not significant, there does appear to be the possibility for an inverse relationship between percent moisture and percent organic matter (Figure 5).

Discussion

Biomass of Grasses and Forbs

The total biomass between the four sections did not vary with years since a burn. Biomass on burned sections of prairie may be related to factors like light, precipitation, and soil moisture (Briggs and Knapp 1995). While light and precipitation were not measured for this study, the sections sampled occur across a small area, so little difference is expected among them. My study did show that the difference in soil moisture among the sections did not vary significantly. If factors that affect biomass did not vary, then I would not expect biomass to vary.

Over years since a burn, I did see a general decrease in the percentage of the total biomass made up of grasses. At the same time, the percentage of the total biomass of forbs increased. Thus, the biomass of grasses and the biomass of forbs appear to have an inverse relationship, which is consistent with other findings (Gibson, D. J. and L. C. Hulbert 1987). Grasses appear to grow best when a mulch layer is absent or reduced (Weaver 1952). Burns reduce the mulch layer, which favors the growth of grasses. However, in years following a burn, the mulch layer increases, which favors the growth of forbs. A second possible explanation for the inverse relationship of grasses to forbs involves competition for resources. It may be that the forbs are better able to tolerate drought, excess moisture, and varying light levels.

Percent moisture and percent organic matter

The lack of a significant difference in the mean of percent moisture in each section sampled isn't a surprise. The areas sampled are close enough to each other that the moisture they would receive from either rain or snow should be consistent, meaning the moisture content of the soil should be similar. The lack of a significant difference in the mean percent organic matter found in each section sampled, as well as the lack of a clear trend, is surprising. We might either expect the percent organic matter to have been highest in the section most recently burned – because the burning helps the decomposition of organic matter – and then decrease with time since the burn; or we might expect the percent organic matter to have been highest in the section least recently burned, because there have been more layers of organic matter that could be decomposed since it last burned. Instead, the two sections with the highest percent organic matter were the sections last burned in 2010 and 2014.

In addition, though not significant, the percent moisture seems to decrease as the percent organic matter increases. Once again, this result is puzzling. We might expect organic matter to be able to hold more water than non-organic matter, which would result in percent moisture and percent organic matter increasing or decreasing together. Instead, I got the opposite trend. It is possible that organic matter can become more closely packed together than non-organic matter, which would limit the amount of water in the soil.

2012

In my tests for the biomass of grasses and forbs, the section burned in 2012 continued to be an outlier. A lower total biomass was found in this location, while the lowest percent of the biomass made up of grasses and the highest biomass made up of forbs was found, contradicting any trends I would have expected. One possibility for this result is that the section burned in 2012 has the smallest area of all the sections I sampled. The smaller area could mean that the rate of natural succession occurring in that area is increased. If area affects succession, then this result might be expected. However, more study is needed on whether the size of a burn section affects the rate of succession.

Conclusions

A plateau did not appear to be reached in either the biomass of forbs or the percent biomass made up of forbs as time since a fire increased. This suggests that the number of years between burns currently used at St. Olaf College is adequate, and could perhaps be extended. However, with the results from the section burned in 2012 not fitting into the patterns seen in the other three sections, further research would be needed before drawing strong conclusions. One could perform the same study each year until each section had been sampled the zero, one, two, and four years after a burn. One could also look into the effect that area of a section might have on its rate of succession after a burn.

Acknowledgements

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Table 1: Mean biomass (g/m^2) for each of the four sections sampled in the St. Olaf College Natural Lands in southern Minnesota in fall 2014.

	Mean	Standard Deviation	p-value
2010	303.20	80.33	0.907
2012	131.20	46.39	
2013	313.80	413.80	
2014	305.00	415.50	

Table 2: Biomass of grasses and forbs found in each of the four sections sampled in the St. Olaf College Natural Lands in fall 2014.

Year	**Biomass Grasses (g/m^2)**	**Biomass Forbs (g/m^2)**	**Total Biomass (g/m^2)**
2010	360.0	246.4	606.4
2012	98.40	164.0	262.4
2013	606.4	21.20	627.6
2014	598.8	11.20	610.0

Table 3: Percent of the biomass made up of grasses and forbs found in each of the four sections sampled in the St. Olaf College Natural Lands in fall 2014.

Year	% Grasses	% Forbs
2010	59.37	40.63
2012	37.50	62.50
2013	96.62	3.38
2014	98.16	1.84

Table 4: Mean percent moisture for each of the four sections sampled in the St. Olaf College Natural Lands in fall 2014.

	Mean	Standard Deviation	p-value
2010 (2002/1998)	19.94	4.08	0.169
2012 (2002)	23.69	2.94	
2013 (1993)	27.50	0.96	
2014 (2002)	22.84	1.03	

Table 5: Mean percent organic matter for each of the four sections sampled in the St. Olaf College Natural Lands in fall 2014.

	Mean	Standard Deviation	p-value
2010 (2002/1998)	6.54	0.57	0.351
2012(2002)	4.97	0.63	
2013 (1993)	4.72	0.49	
2014 (2002)	5.21	1.64	

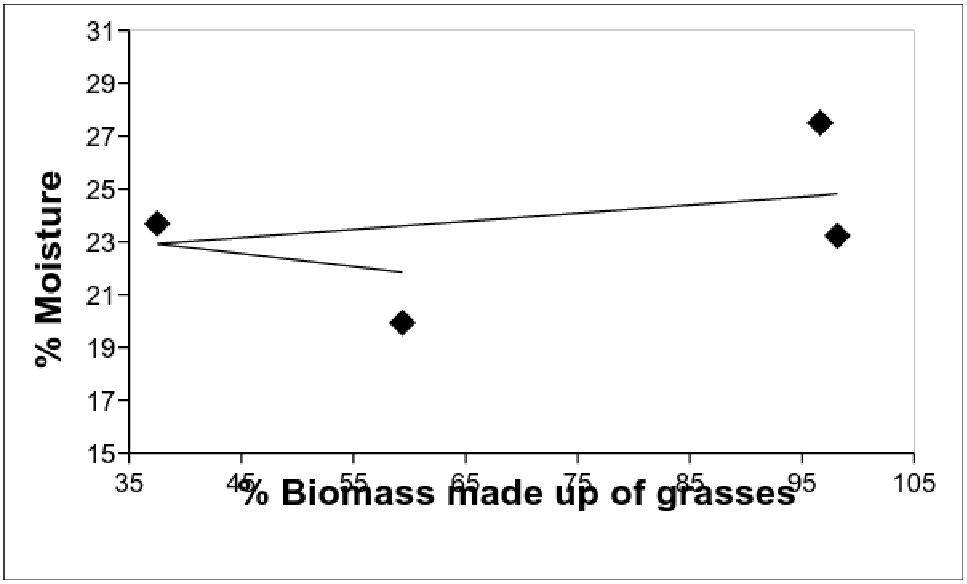

Figure 1: Percent biomass made up of grasses and percent moisture for each of the four sections sampled in the St. Olaf College Natural Lands in fall 2014. t = 0.7537, df = 2, R^2=0.22119, p-value = 0.5297.

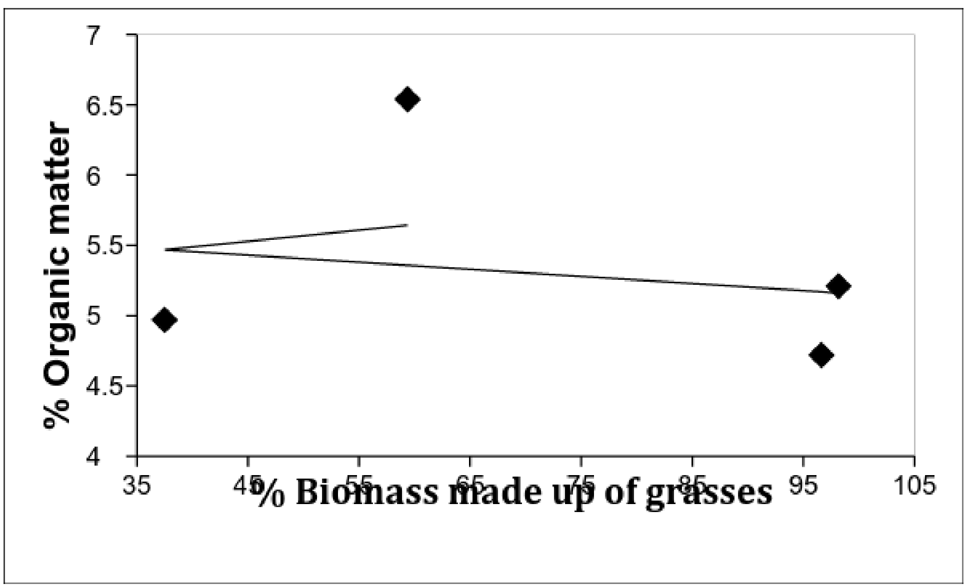

Figure 2: Percent biomass made up of grasses and percent organic matter for each of the four sections sampled in the St. Olaf College Natural Lands in fall 2014. t = -0.4328, df = 2, R^2=0.08565, p-value = 0.7073.

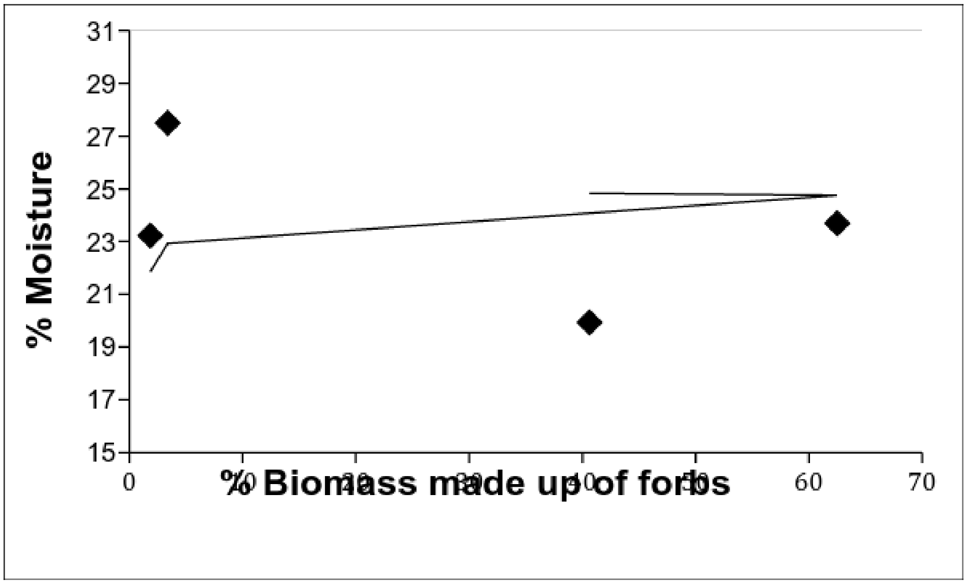

Figure 3: Percent biomass made up of forbs and percent moisture for each of the four sections sampled in the St. Olaf College Natural Lands in fall 2014. t = -0.7533, df = 2, R^2=0.22119, p-value = 0.5299.

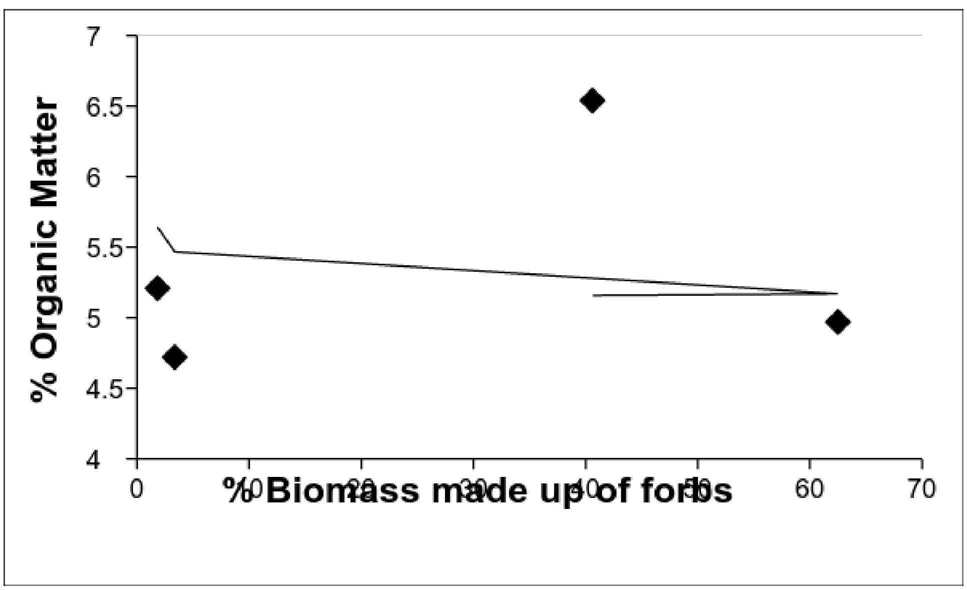

Figure 4: Percent biomass made up of forbs and percent organic matter for each of the four sections sampled in the St. Olaf College Natural Lands in fall 2014. t = 0.4326, df = 2, R^2 = 0.08565, p-value = 0.7075.

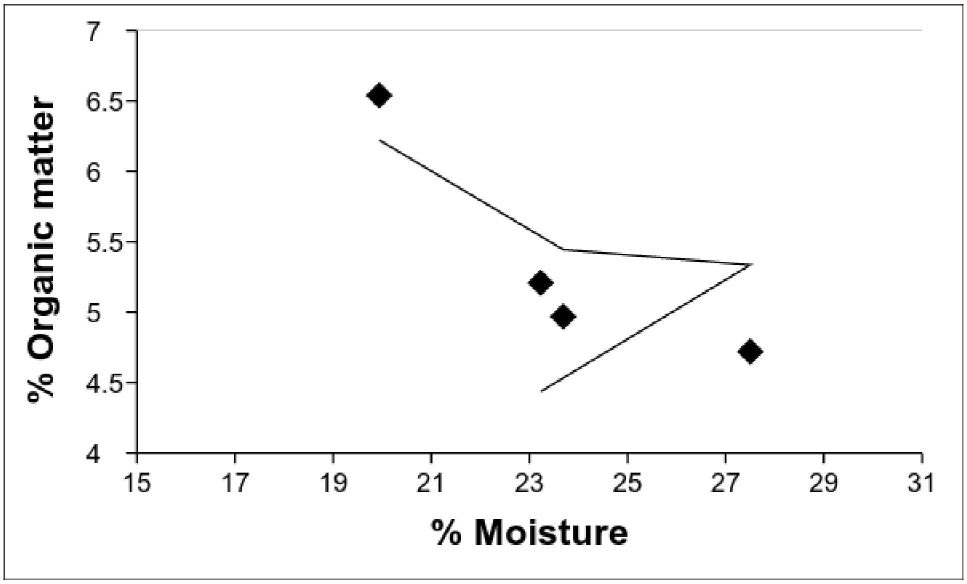

Figure 5: Percent moisture and percent organic matter for each of the four sections sampled in the St. Olaf College Natural Lands in fall 2014. t = -2.9425, df = 2, R^2 = 0.81235, p-value = 0.0987.