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The Influence of Edge Effects and Recreational Trails in a Restored Tallgrass Prairie Ecosystem

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Abstract

The tallgrass prairie was once a prominent ecosystem in North America. However, it is now a fragmented and highly disturbed ecosystem. Although there are many factors that act as disturbance forces in the tallgrass prairie—such as fire, grazing, and agriculture—there are other disturbances that also contribute to the deterioration of the ecosystem. One such disturbance is edge effects, which may be established by recreational trails. Consequently, this study investigated whether trails caused edge effects by examining plant growth as a measure of biomass at three distances in three restored tallgrass prairie sites in the St. Olaf College Natural Lands. The study further examined other factors related to plant growth in the tallgrass prairie including the presence of fire, soil moisture, and organic matter in the soil. The results of this study demonstrated that mean biomass was not significantly different between the different distances from the trail. Instead, they were significantly different between the different prairie sites, with the results being attributed to the presence of recent spring burnings in these sites. Lastly, it was found that the mean percentages of soil moisture and organic matter were significantly different in the distances from the trail, and not significantly different in the prairie sites, which may be attributed to a potential edge effect. Overall, this study suggested that trails do not affect plant growth in the prairie, but may influence soil characteristics. This study may prove useful to the future management of the St. Olaf College natural lands.

Introduction

The tallgrass prairie was once a prominent ecosystem in North America. However, with the rise of industrial agriculture, a majority of the tallgrass prairie has been destroyed and the effort to restore it has left only a handful of small, fragmented remains (Knapp and Seastedt 1998; Koper et al. 2010). According to Samson and Fritz (1994) tallgrass prairies ought to be preserved for not only the inherent value of their rich biodiversity, but for the many economic and social benefits they provide to human society, such as nourishment in food, carbon sequestration, and recreational enjoyment. Thus, the restoration of tallgrass prairie has become of utmost importance.

Some of the primary goals of prairie restoration include decreasing disturbance. One factor of disturbance that researchers have studied in prairies is edge effects. Edge effects are defined as abrupt transitions between two different ecological communities or habitats and are relevant to the tallgrass prairie conservation effort because many prairie restorations are bordered by other ecosystems, are surrounded by agricultural fields, or have trails and roads running through them. Edge effects in the prairie also help to explain the ecosystem's decline and low quality as a result of their small and patchy structure (Koper et al., 2010). Previous studies have further suggested that edge effects in the prairie primarily influence avian nesting patterns (Winter et al. 2000) and plant species diversity and composition (Koper et al. 2010; Lafontaine and Houle 2007). While most prairie disturbances, including edge effects, have been attributed to things like fire, grazing, and agricultural production (Koper et al. 2010; Briggs and Knapp 1995), another less-considered disturbance is the presence of recreational trails.

According to previous studies, trails in the prairie ecosystems can affect a variety of different prairie attributes. Such attributes include higher frequencies of non-native species

(Hansen and Clevenger, 2005; Potito and Beatty, 2005), and changes in the soil's characteristics like moisture, temperature, and nutrient levels (Hawkins, 2011; Parker et al., 1993; Potito and Beatty, 2005). Hansen and Clevenger (2005) further articulate that prairies are some of the most trail- affected ecosystems. Due to these findings, examining the influences of edge effects by trails in the prairie is relevant to its restoration. One factor, however, that has not been extensively studied is how trails affect plant growth and primary production. Thus, the purpose of this study was to examine if the presence of recreational trails created edge effects and consequently affected plant growth in the restored prairies of the St. Olaf College Natural Lands.

More specifically, this study examined how plant growth was affected by trails within the prairie ecosystem. The main objective was to investigate whether trails caused edge effects by examining plant growth as a measure of biomass at three distances in three restored tallgrass prairie sites. It was hypothesized that there would be differences in plant growth among the three distances from the trail, with the nearest distance having the least growth and farthest distance having the most growth. These differences in plant growth would suggest the presence of an edge effect. The second objective of this study examined other factors related to plant growth in the tallgrass prairie including the presence of fire, soil moisture, and organic matter in the soil. It was hypothesized that these factors would have an effect on plant growth and that they would supplement the biomass data obtained, or provide alternative explanations for patterns in plant growth. From this study, implications for the presence of trails on the prairie were investigated, and suggestions for future management were established.

Methods

The location of this project was in the restored prairie of the St. Olaf College Natural Lands (Figure 1). Within this location, there were three different study sites. Site A occurred in the prairie south of the Big Pond trail, which was restored in 1993 and last burned in spring 2013. Site B occurred in the prairie south of the Prairie Loop trail, which was restored in 2004 and last burned in fall 2010. Lastly, Site C occurred in the prairie north of the Prairie Loop trail, which was restored in 2004 and last burned in spring 2016. At each of these sites, plant growth was assessed through the measurement of biomass at different distances from the trail. This data was then used to determine whether or not the trails created an edge effect and were therefore affecting plant growth. All biomass data was collected on October 23, 2016.

Biomass sampling consisted of placing two 50 meter transect lines from a random point adjacent to the trail in each of the three sites, with the transect lines running from the edge of the trail to the interior of the prairie. Along the transect line, there were three plots distanced 1 meter (edge plot), 25 meters (middle plot), and 50 meters (interior plot) from the trail. Using a 50 X 50 cm square frame and loppers, all of the above ground biomass was harvested. A total of 2 transects were placed in each prairie site, with the 2 transects being placed at least 25 meters apart, allowing for 6 plots to occur in each prairie, with 18 plots overall. To ensure that growth from the past year was not included within the biomass measurement, biomass was harvested at about 10 centimeters above the ground. When biomass was collected from each plot, it was placed into a paper bag and labeled accordingly. Once all of the biomass was collected, it was later separated into grasses and forbs, placed in a drying oven for 48 hours, and weighed.

After the biomass was collected, soil samples were taken at each of the 18 plots using a soil corer. All soil samples were collected on November 4, 2016. Once the soil was obtained, it was taken back to a lab and placed into tin jars, and weighed. Soil moisture was obtained by placing soil into the pre-weighed, labeled tins, weighing the tins with the soil, and then placing the tins without their lids into the drying oven for 48 hours. The final weight of the soil was subtracted from the initial weight, and expressed in grams of water per 100 grams of soil. The percentage of organic matter was also measured by placing soil samples into a crucible, after being placing through a 2 mm sieve and weighed between 4.5 and 9 g, at 105 degrees C for 4 hours. Samples were then weighed and the percentage of organic matter was calculated.

Finally, statistical analyses were completed through entering data into an Excel spreadsheet and using the statistical software R and R Commander (i386 3.2.3, 2016) to perform several analyses of variances (ANOVA), linear regressions, and a correlation. The 2-way ANOVA tests were used to examine if there were significant differences in the mean biomass for each prairie site and among plot locations and distances from the trail. Two-way ANOVA tests were also used to determine any significant differences in the soil moisture and percent organic matter for each prairie. Linear regressions were done to determine if there were relationships between soil moisture or organic matter and the amount of total, grass, and forb biomass sampled. Lastly, a correlation was completed to examine the association between the percent soil moisture and the percent organic matter.

Results

Biomass

Between the three prairie sites, there were significant differences in the total mean biomass ($p = 0.01913$, Figure 1), but no significant differences in distance from the trail ($p = 0.29178$). Furthermore, there was no interaction between site and trail distance ($p = 0.07897$); the greatest mean total biomass occurred in the middle plot of Site A (mean = 134.04, SD = 13.10976, Figure 2), while the least mean total biomass occurred in the middle plot of Site B (mean = 50.275, SD = 6.35689, Figure 2). In looking more specifically at the differences in mean total biomass between the different prairie sites, Site C had the greatest amount of biomass (mean = 101.15917, SD = 33.65045, Figure 3) and Site B had the smallest amount of biomass (mean = 59.71333, SD = 14.461, Figure 3), with the greatest differences also occurring between these two sites (p = 0.0381).

Among the biomasses of grasses and forbs, grasses had an overall higher mean (Figure 4). The mean biomasses of grasses were significantly different between prairie site (p = 0.0009153, Figure 4), were not significantly different between distances from trail (p = 0.4858285), and there was no interaction (p = 0.0385120). Among the sites, Site C had the greatest amount of grass biomass (mean = 92.79917, SD = 39.69978, Figure 4), while Site B had the smallest amount (mean = 19.27667, SD = 23.73076, Figure 4). The differences between grass biomass were greatest in Sites B and A (p = 0.01111) and in Sites B and C (p = 0.00259). The mean biomasses of forbs were also significantly different between prairie sites (p = 0.005184, Figure 4), not significantly different between distances from the trail (p = 0.298350), and there was no interaction (p = 0.29835). Among the sites, Site B had the greatest mean forb biomass (mean = 40.436667, SD = 21.038542, Figure 4) and Site C had the least (mean = 8.36, SD = 9.009053, Figure 4). The differences between forb biomass were greatest in Sites B and A (p = 0.00451) and in Sites B and C (p = 0.00372).

Soil

First, the mean percentages of soil moisture were significantly different in distance from the trail (p = 0.0001798), insignificant between sites (p = 0.556784), and there was no interaction (p = 0.133440). The greatest soil moisture was in the middle plots (mean = 37.65909, SD = 3.491411, Figure 5) and was the smallest soil moisture in the edge plots (mean = 27.51842, SD = 3.282598, Figure 5). The differences were greatest between the middle and edge plots (p < 1e-

04) and the middle and interior plots ($p = 0.000251$). Second, the mean percentages of organic matter were significantly different in distance from the trail ($p = 6.931e-05$), insignificant among the sites ($p = 0.7186$), and had no interaction ($p = 0.4005$). The greatest percent organic matter was in the middle plots (mean = 11.581, SD = 1.76, Figure 5), and the smallest percent organic matter was in the edge plots (mean = 5.527, SD = 1.159, Figure 5).

Lastly, linear regressions were performed to examine a variety of relationships among biomass and soil characteristics. First, a linear regression examining the relationship between soil characteristics and total mean biomass depicted a positive, though insignificant trend in the amount of soil moisture ($p = 0.4198$, $r^2 = 0.06814$) and organic matter ($p = 0.2954$, $r^2 = 0.0411$). Second, linear regressions demonstrated insignificant relationships between the amounts of soil moisture ($p = 0.5539$), $r^2 = 0.0223$) and organic matter ($p = 0.75$, $r^2 = 0.006527$) and mean forb biomass. The relationship between amount of soil moisture ($p = 0.78$, $r^2 = 0.005036$) and organic matter ($p = 0.572$, $r^2 = 0.02035$) and the mean grass biomass was also insignificant, but a positive trend. Additionally, a correlation demonstrated a significant association between the percent soil moisture and percent organic matter ($p = 1.414e-06$, $r = 0.880655$, Figure 6).

Discussion

The results of this study demonstrated that the recreational trails through the St. Olaf College restored prairies do not have an effect on plant growth, as indicated by insignificant differences in the mean biomasses between the edge, middle, and interior plots at each site. This result is similar to the study done by Potito and Beatty (2005), who determined that the characteristics of grassland plants were not changed at different distances from the trail. While this result did not maintain the study's initial hypothesis that plant growth would vary at different distances from the trail, it suggested that an edge effect due to trails was not causing disturbance in this particular prairie ecosystem, which is beneficial knowledge to the maintenance of these trails and prairie lands.

In looking at what did affect plant growth, however, there were significant differences in the mean biomasses of prairie Sites A, B, and C (Figures 2, 3). These differences can likely be attributed to the fact that each of these prairies was last burned at different points in time. According to Abrams et al. (1986) and Briggs and Knapp (1995), mid- to late-spring burning in the tallgrass prairie results in higher levels of plant growth as compared to unburned prairies. Similarly, this study also found that sites with most recent spring burns were those with the highest biomass (Figure 3). More specifically, the site with the overall greatest biomass was Site C, which was most recently burned in spring 2016, followed by Site A, which was last burned in spring 2013, and then by Site B, which was last burned in fall 2010. While the results of this study did not provide evidence for the effects of a trail (as measured by distance from trail) in the prairie, it did provide data in line with previous studies on the role of fire in the tallgrass prairie, which is vital to the productivity of the ecosystem (Abrams et al., 1986).

Although the total biomass was found to differ among the prairie sites, in looking more specifically at the grasses and forbs, it can be seen that overall plant growth was highest in grasses (Figure 4). Again, these results may be ascribed to the role of prairie burning. In both of the sites that were most recently burned (A and C), there were higher amounts of grasses. In the site that was burned the longest ago (B), though, there were higher amounts of forbs, which is also in line with the study done by Abrams et al. (1986). The study suggested that an increase in forbs was due to an absence of fire, and was likewise shown in this current study. Similar results were also found by Briggs and Knapp (1995), who explained that forb primary production is limited by biotic interactions, and that grasses are able to outcompete forbs for resources like water and nutrients. This result was further suggested by Augustine et al. (2014), who focused on the effect of fire on C_3 plants, which forbs often are. From the results of both past studies and this study, a potential avenue for further research may be in examining the biotic interactions among grasses and forbs with regards to the presence of a trail and fire, and these factors' effects on these interactions.

Additionally, this study demonstrated how a variety of factors—like fire or soil— can influence plant growth in the prairie (Briggs and Knapp, 1995). Therefore, one of the additional factors that can affect plant growth is soil. While plant growth itself appeared unaffected by the presence of the trail, soil characteristics were. In both the mean percentages of soil moisture and organic matter, there were significant differences in the edge, middle, and interior plots away from the trail (Figure 5). These results suggest that the trails may impact soil. Because the trails in the St. Olaf College prairies are recreational trails, they are susceptible to soil compaction, which increases overland water flow and runoff, away from the trail (Weintraub, 2011). Since the greatest soil moisture was found in the middle plots (Figure 5), this may be a result of water not seeping into the trail soils and instead flowing off the trail and into the prairie, as was suggested by Weintraub's (2011) study. These findings suggest that trails have important consequences for the hydrology of the prairie, and that the presence of trails may affect it, though additional research is recommended to explore these observations.

Conclusions

While this study depicted that plant growth was not ultimately affected by the presence of trails in the St. Olaf College prairie natural lands, and instead that the trails were perhaps affecting the lands' soils, further research is needed to verify these assumptions, as well as to further explore how the soil is being affected. Such research may include examining different characteristics of the trail, such as the trail material, width, and frequency of use, as did Potio and Beatty (2005), and the impact these characteristics have on soil. Understanding the impact of trails in prairie ecosystems is important for the management and preservation of the remaining prairies. While recreational trails allow humans to enjoy and spend time in these remarkable ecosystems, it is important to monitor the impact of these trails, so that people of all generations can continue to enjoy the prairies for years to come.

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List of Figures

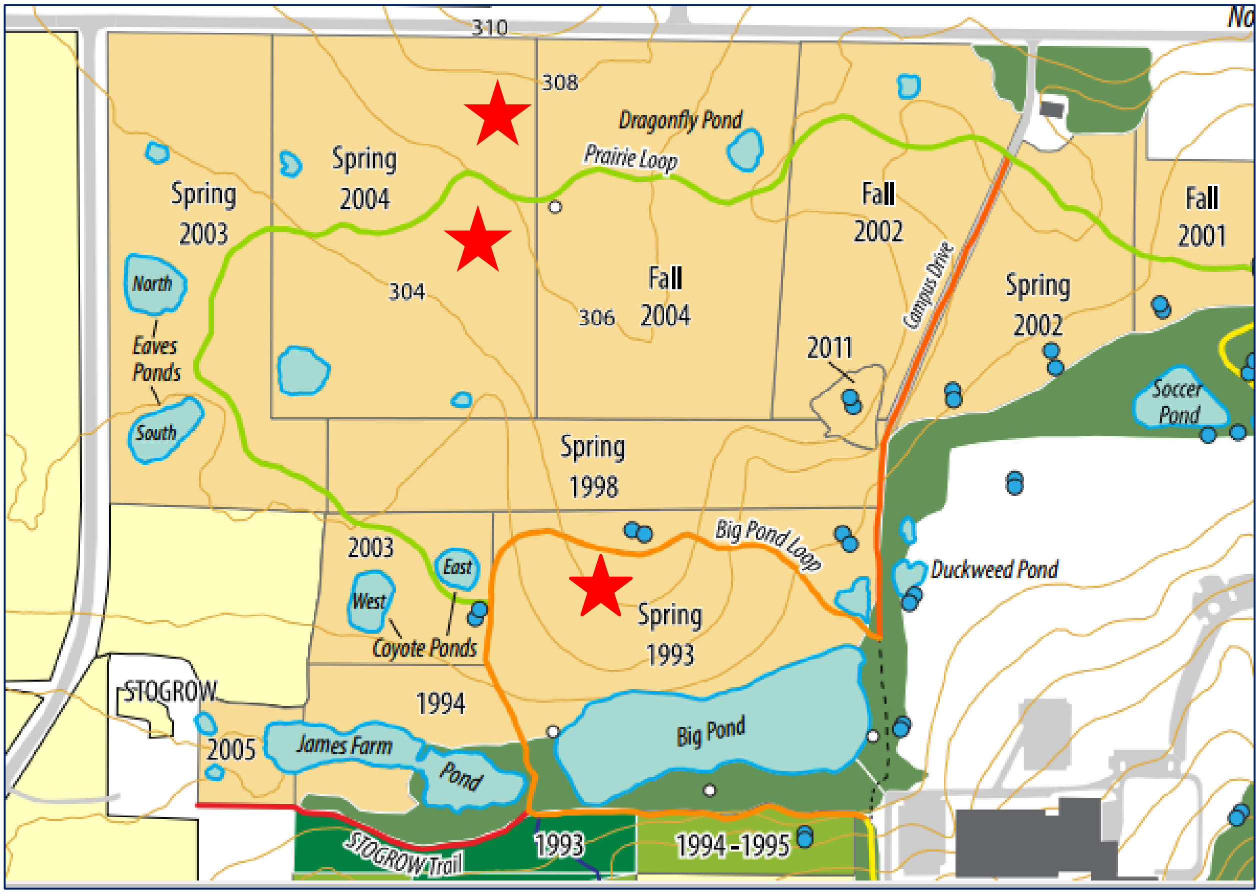

Figure 1: Map of the St. Olaf College Natural Lands, where the red stars indicate the studied sites.

Mean Total Biomass Among Sites and Distance from Trail				
Site P-Value = 0.01913; Distance P-Value = 0.29178; Interaction P-Value = 0.07897				
Site	**Distance from Trail**	**Means**	**Standard Deviation**	**Counts**
A	Edge	67.17	28.96	2
A	Interior	115.625	1.78898	2
A	Middle	85.66	18.908	2
B	Edge	71.94	7.127	2
B	Interior	56.925	21.488975	2
B	Middle	50.275	6.35689	2
C	Edge	76.34	43.345646	2
C	Interior	93.0975	9.316132	2
C	Middle	134.04	13.10976	2

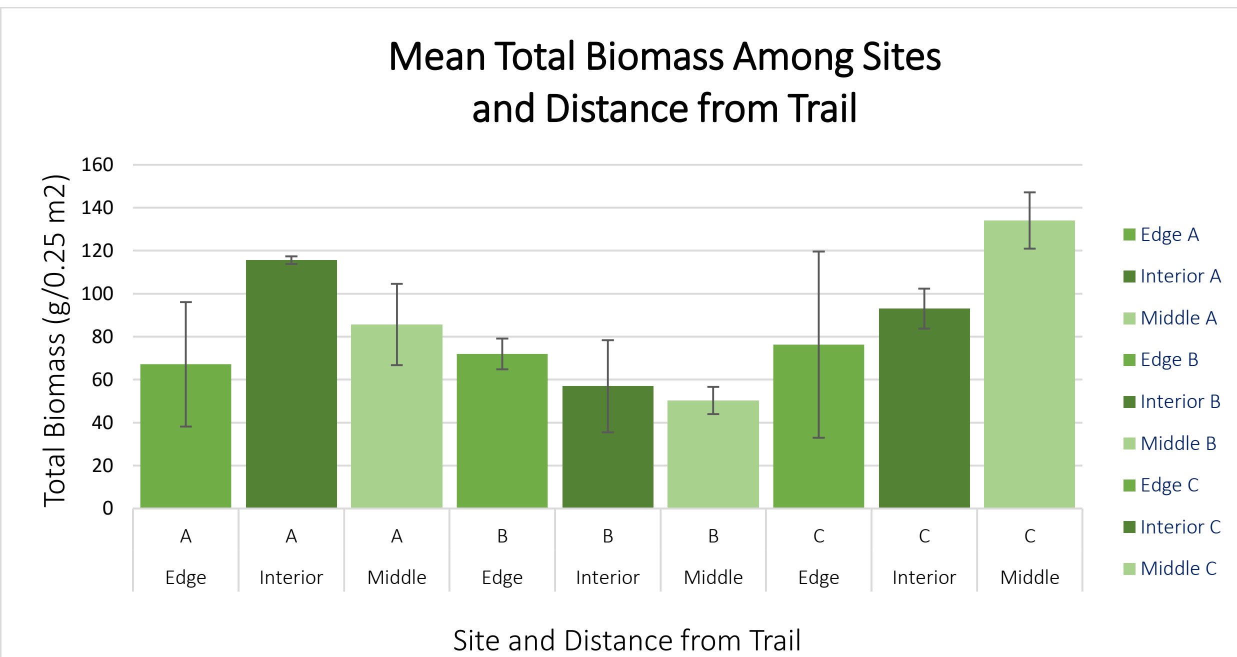

Figure 2: ANOVA results depicting significant differences in the mean total biomass between prairie sites (p = 0.01913) and insignificant differences between distances from the trail (p = 0.29178).

Mean Total Biomass Among Sites				
P-Value = 0.0193				
Site	**Prairie Last Burned**	**Mean Biomass**	**Standard Deviation**	**Counts**
A	Spring 2016	89.485	26.80057	6
B	Spring 2013	59.71333	14.46158	6
C	Spring 2010	101.15917	33.65045	6

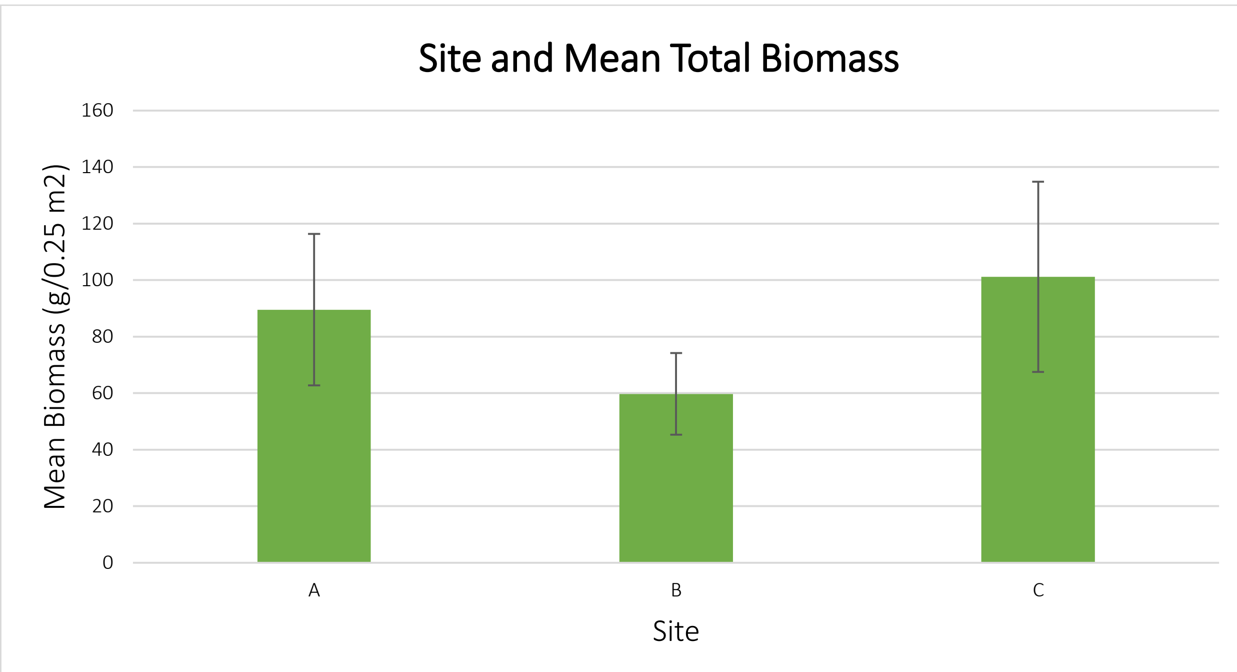

Figure 3: ANOVA results depicting the significant differences between prairie sites (p = 0.0193) and means of total biomass.

Mean Biomass Between Grasses and Forbs in Sites					
	P-Value (Grasses) = 0.00221		**P-Value (Forbs) = 0.00175)**		
Site	**Mean Biomass in Grasses**	**Standard Deviation**	**Mean Biomass in Forbs**	**Standard Deviation**	**Counts**
A	80.24833	28.38795	9.236667	8.857053	6
B	19.27667	23.73076	40.436667	21.038542	6
C	92.79917	39.69978	8.36	9.009053	6
Total:	**192.32417**		**58.033334**		

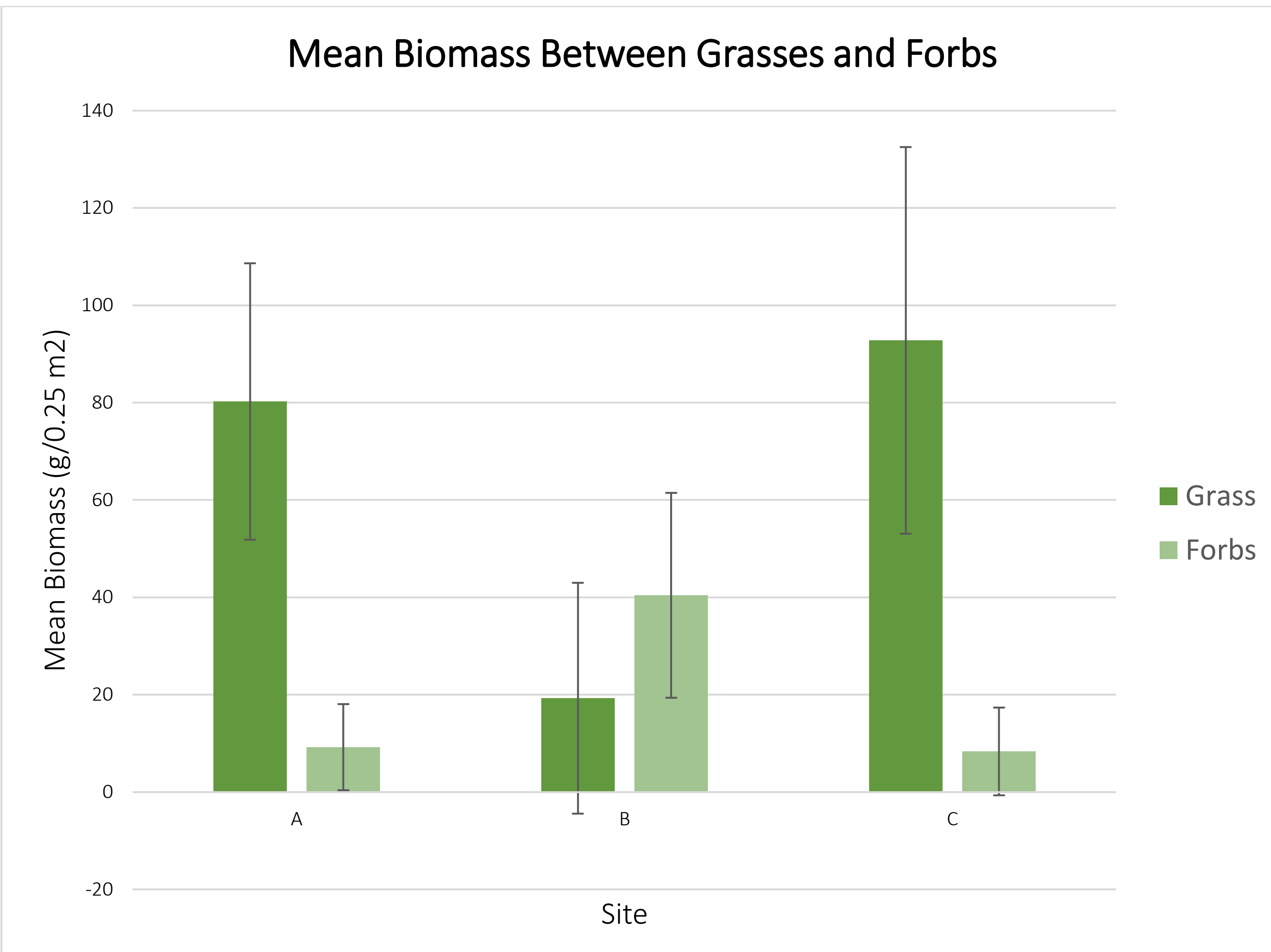

Figure 4: ANOVA results depicting the difference in biomass amounts between grasses and forbs, with each having significant differences among prairie sites (p = 0.00221; p = 0.00175).

Mean % Soil Characteristics and Distance from Trail					
	P-Value (Soil Moisture) = 5.86e-05		P-Value (Organic Matter) = 2.18e-06		
Distance from Trail	**Mean % Soil Moisture**	**Standard Deviation**	**Mean % Organic Matter**	**Standard Deviation**	**Counts**
Edge	27.51842	3.282598	5.527	1.159	6
Interior	28.06804	2.510064	7.0719	0.799	6
Middle	37.65909	3.491411	11.581	1.76	6

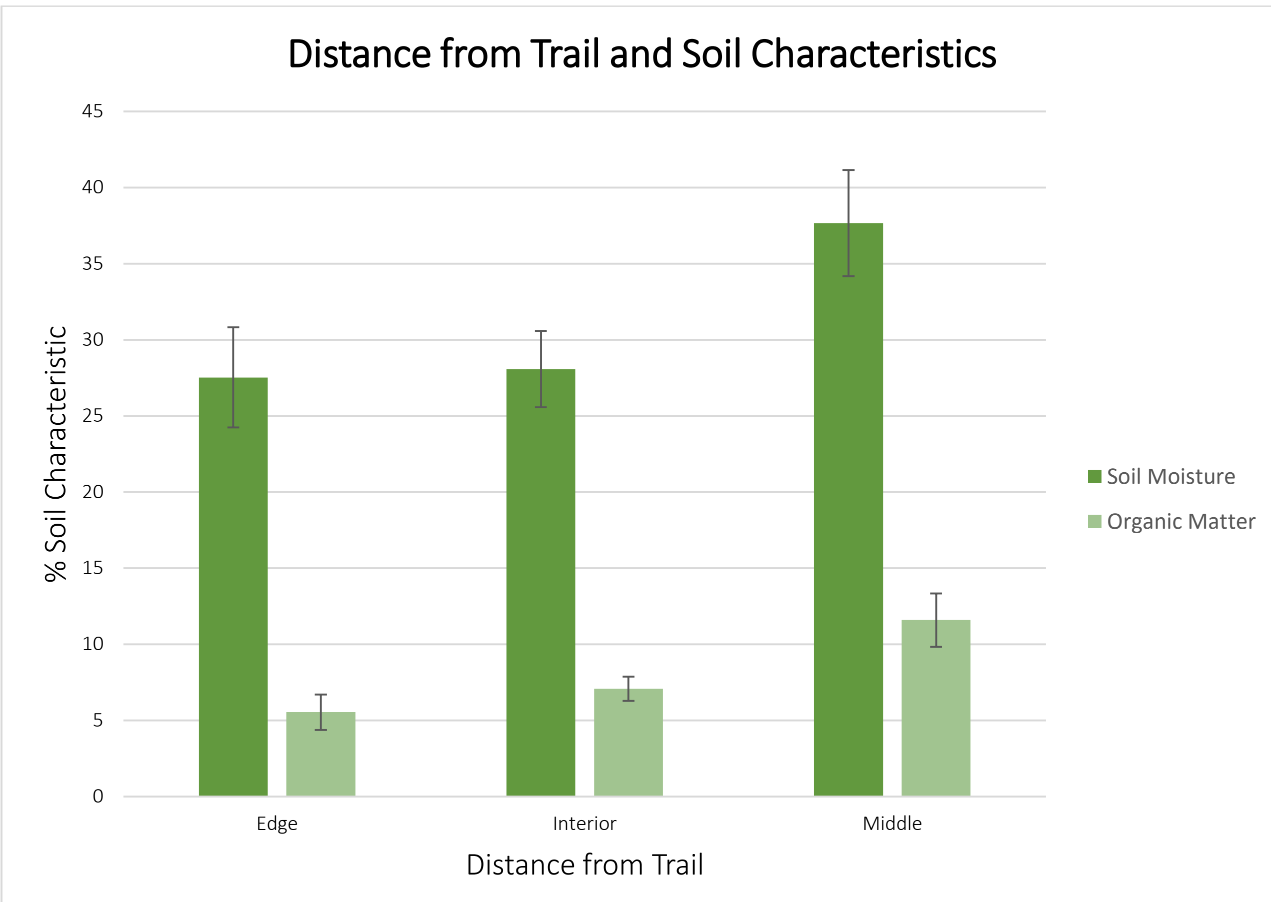

Figure 5: ANOVA results depicting the significant differences in soil moisture (p = 5.86e-05) and organic matter (p = 2.18e-06) at different distances from the trail.

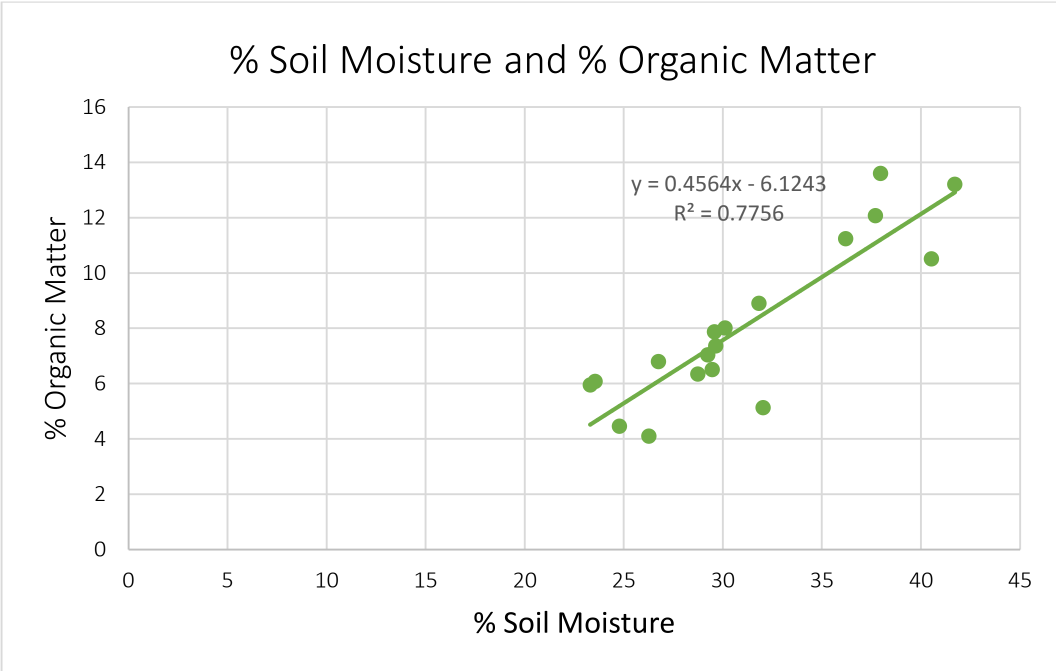

Figure 6: Correlation depicting the significant, positive association between percent soil moisture and percent organic matter ($p = 1.414e\text{-}06$, $r = 0.880655$).