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The Effects of Clipping on the Biomass Production of Native Warm Season Grasses on Reclaimed Abandoned Coal Mine Soils

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THE EFFECTS OF CLIPPING ON THE BIOMASS PRODUCTION OF NATIVE WARM SEASON GRASSES ON RECLAIMED ABANDONED COAL MINE SOILS

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An Abstract of the Thesis by
James Arthur Kent Daniel

Strip mining leaves behind highly disrupted plant and soil communities. Mined land reclamation returns the land back to a natural or economically usable state, however, reclamation cannot completely restore the soils to their original state. Subsequently, normal frequencies of management practices may not be as effective as in undisturbed soils. Understanding how the severity of soil disturbance affects plant production is important for habitat rehabilitation and determining effective management techniques to be implemented following reclamation. This project addresses the questions of whether biomass production in warm season grasses on reclaimed coal mines is promoted or inhibited by clipping, and how clipping frequency affects productivity. Grasses were clipped to simulate mowing at three reclaimed mine sites and three undisturbed control sites. Three groups samples labeled A, B, and C were clipped three, two, and one times respectively.

Biomass production was reduced when grass was clipped before peak biomass production. An increase in clipping events reduced production even more. There were no significant differences between the disturbed and undisturbed sites suggesting that whether disturbed or not, cutting before peak production decreases overall biomass production. Analysis of treatments from all the sites showed the treatments that were clipped multiple times were significantly different from the treatment that was clipped once at peak production. Analysis of sites individually showed most sites did not show significance. Higher rates of clipping did not show significance. While not significant at most individual sites, biomass production was higher when samples were only clipped once, at peak biomass production and an increase in clipping decreased the grasses' ability to recover after clipping in both disturbed and undisturbed sites.

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CHAPTER I

INTRODUCTION

Southeast Kansas was mined extensively beginning in the late 1870's when the Scammon brothers sunk the first mine shaft in Cherokee County, but by the 1930's surface strip mining became the preferred method of mining coal from areas where the coal was too shallow and thin to be mined underground (Young and Allen 1925, Powell 1972). Because the coal is extracted from geologic strata generally not accessible from the surface, damage to the flora and fauna of the area is extensive and can persist for decades (Buehler and Percy 2012).

Strip mining has highly disruptive impacts on surface and ground water, soil, native vegetation, and wildlife populations and leaves behind pollutants and piles of waste material from the mining process (Buehler and Percy 2012, Kundu and Ghose 1997, Ghose 2005, Rashid et al. 2014). To reduce the impact of mining on the environment, legislation was enacted requiring the mined land be reclaimed. In 1969 Kansas passed regulations requiring coal companies to reclaim the land. Later, in 1977, the federal government passed the Surface Mining Control and Reclamation Act (SMCRA) requiring that surface coal mines be reclaimed when the mining operations ceased, and SMCRA also provided funds for the reclamation of coal mines abandoned prior to 1977 (Surface Mining Control and Reclamation Act, 1977).

Mine reclamation is a process of restoring mined land back to a natural or economically usable state. Cool season grasses like tall fescue (*Festuca arundinacea*) and perennial ryegrass (*Lolium perenne*) are often used to reseed reclaimed mines because they mature and become established quickly which stabilize the soil quickly (Green and Franz 1986). However, native warm season grasses are more ecologically desirable because they provide excellent habitat for the native wildlife (Capel 1995). Tall fescue provides poor habitat and no nutritional value (Barnes et al. 1995, Coley et al. 1995, Conover and Messmer 1996a, Conover and Messmer 1996b, Guiliano et al. 1994, Madje and Clay 1991).

While reclamation of abandoned mined land in southeast Kansas has been able to re-establish warm season grass communities, the reclamation processes cannot restore soils back to pre-mining condition. Native soils of midwestern North America developed over thousands of years. Re-establishing soil nutrient cycles and microbial processes are critical for long term reclamation (Singh et al. 2002, Lone et al. 2008, Kavamuro and Esposito 2010). Soil aggregates and structures establish soil's ability to perform essential ecological roles, (water storage, insulation, nutrient cycles, etc.). In most reclamation efforts, only a few inches of top soil is placed over the graded spoil and overburden, and new horizons take decades to centuries to develop. This makes for very poor soil and growth conditions for vegetation.

Having such poor quality soils on reclaimed coal mines in SE Kansas raised a question as to the effectiveness and frequencies of implemented grassland management. Periodic burning, mowing, and rotational grazing are used for grassland management. Grasses respond to recover from disturbances like fire and herbivory. Under certain circumstances these pressures can even enhance growth (McNaughton 1984, Knapp et al. 2012). The question has been raised: are warm season grasses on reclaimed abandoned coal mine soils recovering adequately from disturbances caused by prairie management techniques.

The goals of this project were 1) to determine if biomass production in warm season grasses on reclaimed coal mines are promoted or inhibited by clipping compared to undisturbed soils and 2) determine at what frequency of clipping are these effects maximized or minimized compared to undisturbed soils. The hypotheses are: 1) biomass production on native warm season grasses, in response to the clipping, will be lower on the disturbed soils of the reclaimed mines then on the undisturbed soils of the control sites and 2A) an increase in clipping frequency will correlate with a decrease in biomass production on the reclaimed sites and 2B) that decrease in production will be less on the undisturbed sites than the disturbed soils. These hypotheses were addressed with biomass data collected the growing season of 2015 from three paired grassland sites in SE Kansas.

CHAPTER II

SITE DESCRIPTION

Three sites of varying post-reclamation ages were chosen. Each has a corresponding reference site of undisturbed soil that is located within one kilometer from the reclaim. The three reclaimed sites were chosen based upon species composition, the age of the reclamation, and available relatively undisturbed land of the same species composition for a reference/control site. The species of interest at these sites were native warm season grasses including Big Bluestem (*Andropogon gerardi*), Little Bluestem (*Schizachyrium scoparium*), Indiangrass (*Sorghastrum nutans*), Switchgrass (*Panicum virgatum*), and Sideoats Grama (*Bouteloua curtipendula*). Before the sites were chosen, they were examined to make sure native warm season grasses were dominant.

The distance between the disturbed sites and the paired undisturbed sites varied. Google Earth was used to measure the distance between the pairings for each of the three sites. All three pairings were separated by less than one kilometer. The first two disturbed sites are Mined Land Wildlife Areas (MLWA) belonging to The Kansas Department of Wildlife, Parks, and Tourism (KDWPT). The third site is managed by the

Pittsburg State University Biology Department. The undisturbed sites were private land, a MLWA, and a prairie that is managed by the PSU Biology Department.

KDWPT Mined Land Wildlife Area

The MLWA is comprised of 47 units across southeast Kansas totaling 14,500 acres. Surface mining occurred on the majority of the land (KDWPT: Mined Land Wildlife Areas 2019). About 9,000 acres of the MLWA is woodland consisting of oaks, walnut, hickory, and hackberry with an understory of dogwood, green briar, honey suckle, and poison ivy and about 4,000 acres consist of native warm season grasses with some cool season grasses (KDWPT: Mined Land Wildlife Areas 2019). The remaining 1,500 acres are strip pit lakes (KDWPT: Mined Land Wildlife Areas 2019). Much of the MLWA has had some reclamation completed with plans for more to be done in the future.

Site 1D: MLWA Unit 6

The first disturbed site is the KDWPT Mined Land Wildlife Area Unit 6. It is located two miles east of Pittsburg on 560 Ave. Reclamation on unit 6 was completed in 2009 with 90.5 acres reclaimed. The reclaimed area of unit 6 that was sampled consisted of earthwork that filled most of a strip pit that paralleled 560 Ave. KDWPT used a seed mix of Switchgrass (*Panicum virgatum*), Little Bluestem (*Schizachyrium* *scoparium*), Big Bluestem (*Andropogon gerardi*), Sideoats Grama (*Bouteloua curtipendula*), Indiangrass (*Sorghastrum nutans*), Perennial Rye (*Lolium perenne*), Birdsfoot Trefoil (*Lotus corniculatus*), and a mixture of forbs as well as some other grasses for erosion control in some areas (KDHE-Surface Mining Section Staff et al. 2005).

Since 2009, the warm season grasses have become well established on the meadows of the reclamation that parallel 560 Ave, and they are the dominant species with a few forbs interspersed throughout the area. The south meadow has become well established with the warm season grasses with interspersed forbs. However, by mid-August, the majority the southern meadow becomes overgrown with forbs.

Site 1U: Hough Farm

The undisturbed reference site for site 1D is privately owned property .99 kilometers to the east of site 1D on the southeast corner of 560 Ave. and 200th St. The sampled section is approximately eighteen acres in size. The soil on the site is comprised of Parson's silt loam (Soil Survey Staff 2019). The A horizon in Parson's silt loam reaches to a depth of eight inches (Soil Survey Staff 2019). The plant community on the site is comprised primarily of warm season grasses including Big Bluestem (*Andropogon gerardi*), Little Bluestem (*Schizachyrium scoparium*), Switchgrass (*Panicum virgatum*), and Indiangrass (*Sorghastrum nutans*). There is a nine to ten-meter fire lane surrounding the site that is planted in cool season grass. The land is not grazed or cut for hay. To the land owner's knowledge, the area has never been farmed.

Site 2D: MLWA Unit 12

The second disturbed site is on MLWA Unit 12. It is at the intersection of NE 10th St and NE Star Valley Rd in Cherokee county. Reclamation on Unit 12 was completed in 1998 and 2000. The section of the reclamation that was sampled is approximately five acres. There was no strip pit lake, and the area was covered with tailings from the mining process.

The seed mixture consisted of Big Bluestem (*Andropogon gerardi*), Little Bluestem (*Schizachyrium scoparium*), Indiangrass (*Sorghastrum nutans*), Switchgrass (*Panicum virgatum*), Sideoats Grama (*Bouteloua curtipendula*), and a variety of forbs among a few other species for erosion control (KDHE-Surface Mining Section Staff et al. 1998). Today the warm season grasses have become well established and are the dominant species. The invasive species, Sericea lespedeza (*Lespedeza cuneata*), has also become established, and grows in moderate to large patches throughout the site.

Site 2U: MLWA Unit 14

The undisturbed site for 2D is on the MLWA Unit 14. It is approximately half a mile west of site 2D on Star Valley Rd. It is a small section of land approximately three acres in size that is surrounded by abandoned surface mines but has remained undisturbed. The undisturbed soil continues on the north side of Star Valley Rd. However, it was not used due to the large amount of sumac growing throughout this meadow. The soil on Site 2U is comprised of Dennis silt loam (Soil Survey Staff 2019). The A horizon in Dennis silt loam reaches to a depth of eleven inches (Soil Survey Staff 2019). The site is dominated by a thick growth of Big Bluestem (*Andropogon gerardi*), Little Bluestem (*Schizachyrium scoparium*), Indiangrass (*Sorghastrum nutans*), Switchgrass (*Panicum virgatum*), and Sideoats Grama (*Bouteloua curtipendula*) as well as some forbs. There are a few deciduous and evergreen trees and some sumac.

<u>Site 3D: The Monahan Outdoor Education Center</u>

The Monahan is 156 acres located about a ½ mile west of 170th St on 510 Ave in Crawford County. It was donated to the PSU Biology Department in 1988. It was shaft mined between 1899 and 1918 and surface mined in the 1930's (USDA, SCS 1981a). In addition, it was a tipple site in which coal was brought to be processed. The processing of all the coal left behind waste material in a large slurry pond and gob pile (Bailey et al. 2017). The waste material consisted of shale, pyrite, and coal. The site was extremely acidic and did not re-vegetate for forty years because of the extreme conditions.

Reclamation was completed in the spring of 1985. The reclamation included constructing erosion control, cleaning up of the acid pits and tipple site, reshaping of the gob pile into an eastward slope, adding limestone and soil, and constructing a drainage ditch and outlet terraces. Warm season grasses were planted by 1987. Today Big Bluestem (*Andropogon gerardi*), Little Bluestem (*Schizachyrium scoparium*), Indiangrass (*Sorghastrum nutans*), Switchgrass (*Panicum virgatum*), Sideoats Grama (*Bouteloua curtipendula*) have become well established. Forest surrounds the grasses on the west and south of the property. There is a strip pit lake on the west side along with a wetland on the southwest corner of the property.

<u>Site 3U: The O'Malley Prairie</u>

The O'Malley Prairies are two tracts of undisturbed land totaling about 3.6 acres in size. They are approximately 0.8 kilometers east of the Monahan at the intersection of 170th St and 510 Ave. The soil on the site is comprised of Hepler silt loam, Kanima silty clay loam, and Parson's silt loam (Soil Survey Staff 2019). The A horizon in Hepler silt loam and Kanima silty clay reaches to a depth of nine inches and six inches respectively (Soil Survey Staff 2019). Though small in size, they are diverse in species which consist Big Bluestem (*Andropogon gerardi*), Little Bluestem (*Schizachyrium scoparium*), Indiangrass (*Sorghastrum nutans*), Switchgrass (*Panicum virgatum*), Sideoats Grama (*Bouteloua curtipendula*) and a variety of forbs. Though the soil on the O'Malley is undisturbed, it is mowed every year for hay. This is also a field site for the Pittsburg State University biology department.

CHAPTER III

MATERIALS AND METHODS

All sites were sampled in June, July, and August of 2015. Sampling was completed between the 9th and the 15th of each month. All six sites had ten sampling points with three sub sampling points. Each of those three sub points were grouped based on the number of times it was clipped. One sub sampling point was clipped three times (group A), one clipped two times (group B), and one clipped once (group C) throughout the season making a total of 360 samples. Sample points were randomly selected in the beginning of June just prior to sampling.

Sampling Point Placement

Transects were created for each site using Google Earth. The coordinates of the beginning point, the length, and the bearing of each transect were recorded. More transects than were needed were created in anticipation of the possibility that transects may have to be rejected due to the species composition along any given transect. Each transect was placed no closer than ten meters to the edge of any other habitat type or body of water to avoid sampling from locations which may be affected by another habitat type.

A random number generator was used to select sampling points along each transect. The minimum number was #1, and the maximum number was the length of the transect in meters. Once a number was generated, the transect was walked that distance in meters starting from the beginning coordinates and following the bearing for that transect. If the species composition at a sample point was not composed of the target species, then it was rejected and the sample point was randomly place at a different location on the transect. At each sampling point, three flags were placed for each of the three sub points (groups A, B and C). This process was followed until all ten sampling points for each site has been placed.

Sample Collection

The first clippings of the A group were collected in June. In July the second clippings of the A group and the first clippings of the B group were collected. In August the third clippings of the A group, the second clippings of the B group, and the clippings of the C group were collected. All plants in the sampling hoop were clipped between five and seven centimeters from the ground and placed in large brown paper bags and marked with the sample number.

Sample Processing

Once the samples were taken back to the lab, each was air dried and sorted by separating out the current season's growth from the previous season's standing dead. The standing dead was discarded, and current growth was dried at 70^{o} C for one week. Sample biomass was pulled from the ovens and placed in desiccators to prevent them from absorbing atmospheric water while they cooled. Once cooled, they were weighed to the nearest tenth of a gram.

CHAPTER IV

RESULTS

Data for site 3U was used in the preliminary analysis, but it was left out of the statistical analysis due to the loss of August samples for the site. Due to a mistake in the lab, one sample each from 1D and 1U was lost. Preliminary analysis was done with a comparison of the average biomass produced from treatment groups A, B, and C for each site. This comparison showed a noticeable effect of clipping on biomass production. The A and B groups had a sharp decline in production compared to the C samples that were clipped only once at the peak of the growing season in Kansas. This comparison for site 1D showed treatment A had a total production of 45.9 g/m^2, B had a total production of 57.3 g/m^2, and C had a total production of 59.3 g/m^2 (Figure 1). Site 2D had a similar decline in production. Treatment A produced 65.4g/m^2, treatment B produced 62.0 g/m^2, and treatment C produced 75.4 g/m^2 (Figure 2). Site 3D had a larger decline. Treatment A produced 39.6 g/m^2, treatment B produced 42.7 g/m^2, and treatment C produced 68.3 g/m^2 (Figure 3).

Undisturbed site 1U showed a decline in production in the A and B groups, but it had a higher production than site 1D. Treatment A at 1U produced 49.9 g/m^2, treatment B produced 54.6 g/m^2, and treatment C produced 67.7 g/m^2 (Figure 4). Site 2U had less of a decline in production for group A. Group B showed a complete compensation in biomass production having approximately the same weight for groups B and C. Treatment A produced 49.9 g/m^2, treatment B produced 58.9 g/m^2, and treatment C produced 56.6 g/m^2 (Figure 5). Site 3U had an over compensation response in treatment A after clipping in June. Treatment A produced more biomass than treatment B. Treatment A produced 57.7 g/m^2 and treatment B produced 44.2 g/m^2 (Figure 6).

ANOVA results for treatment, site, and treatment + site from all of the sites (both disturbed and undisturbed) showed site had a p-value of 0.012, treatment had a p-value of 0.001, and treatment + site had a p-value of 0.463 (Table 1). Using one-way ANOVA, multiple comparisons for Site and Treatment were done. Site 2D and 3D were the only sites statistically different (Table 2). Treatment C is statistically different from A and B, but Treatment A and B are not statistically different from each other (Table 3).

An ANOVA was also run on all three treatments for each site individually. Only site 3D showed significance in the treatments with a p-value of 0.004 (Table 4). Treatments A and B were not significantly different from each other, but treatment C was significantly different from A and B (Table 5). A One-Way ANOVA Power Analysis was done with an effect size of 0.5. The power of the analysis was 63.52% (Table 6).

CHAPTER V

DISCUSSION

The results appear to support the hypothesis that clipping decreases biomass production; however, there was no significant difference between the disturbed and undisturbed sites. This was unexpected and did not support the hypothesis that the undisturbed sites would have higher production than the disturbed sites. This suggests that whether soils are disturbed or not, cutting earlier than peak production decreases the overall biomass produced and the warm season grasses are not recovering any better on the undisturbed soils.

Sites 2D and 3D were significantly different (Table 1, Table 2). These two reclamations occurred 13 years apart (1985 and 1998 respectively). Site 1D, where reclamation was completed in 2009 is the most recently completed site. Because 1D is the most recent reclamation, it was expected that it would be the least productive. However, it was not significantly different from either of the two older sites, and it produced a total biomass that was between the two older reclamations: 1D = 162.5 g/m^2, 2D = 202.8 g/m^2, 3D = 150.6 g/m^2. These results suggest that the differences between the disturbed sites is due to site conditions rather than treatment.

Site conditions probably contribute to other unexpected results in this project. For example, site 3D was 30 years old at the time of sampling, and it might be expected to have a more established and therefore more productive plant community. However, it was not significantly different from the youngest site (1D). The history of site 3D is that of a "gob pile", where coal was washed and especially severe contamination occurred at the site (Bailey et al 2017). The severity of the disturbance at 3D suggests that the length of time it will take for the plant community to become stable may be extended.

When treatments from all the sites (both disturbed and undisturbed) were analyzed, treatment was significant ($p = 0.001$). Treatment C (only clipped once) was significantly different from treatment A (clipped three times) and B (clipped two times). However, when each site was analyzed alone, there was only significance at site 3D, where C was different from A and B ($p = 0.004$). This suggests that more sampling at each site might have revealed significant differences at the individual sites. The results of the power analysis being 63.52% (Table 6) supports this. In contrast, it may be that the plant communities at the individual sites do not yet have sufficient soil resources to be able to compensate for the clipping regime.

In summary, the warm season grasses did not produce statistically significant differences in biomass with higher rates of clipping. However, this project did note that, while not significant at most sites, biomass production was higher when samples were only clipped once, at peak biomass production. An increase in clipping decreased the grasses' ability to recover after clipping in both disturbed and undisturbed sites. This could be important information for future management in this region as well as for future studies.

Regarding management decisions, this study suggests that plant communities in SE Kansas may produce maximum biomass when only clipped once, at peak biomass. Additional harvest may reduce total biomass production. Regarding future studies, it seems unnecessary to clip three times as was done in this project, because there is little evidence that managers would harvest three times a season. Additionally, this study did not reveal that disturbed soils are responding differently from the undisturbed soils, and this could be because disturbed sites display a wide variety of conditions, both pre- and post-reclamation. When all of the sites were combined and not divided into disturbed versus undisturbed categories, they began to reveal significant differences. Increasing the number of sampling sites regardless of the level of disturbance might make an extended study, over several years, simpler to organize.

Analysis of Variance Including Site*Treatment Interaction					
Source	DF	Adj SS	Adj MS	F-Value	P-Value
Site	4	5118	1279.6	3.32	0.012
Treatment	2	5939	2969.7	7.71	0.001
Site*Treatment	8	2985	373.1	0.97	0.463
Error	133	51212	385.1		
Total	147	65356			

Model Summary

S	R-sq	R-sq (adj)	R-sq (pred)
19.6228	21.64%	13.39%	2.87%

Table 1.

Site Grouping Information Using the Tukey Method and 95% Confidence				
Site	N	Mean	Grouping	
2D	30	67.59	A	
1U	29	57.8	A	B
2U	30	55.12	A	B
1D	29	53.96	A	B
3D	30	50.17		B

Table 2.

Treatment Grouping Information Using the Tukey Method and 95% Confidence			
Treatment	N	Mean	Grouping
C	49	65.58	A
B	50	55.09	B
A	49	50.19	B

Table 3.

Analysis of Variance for Site 3D					
Source	DF	Adj SS	Adj MS	F-Value	P-Value
Treatment	2	4977	2488.4	6.86	0.004
Error	27	9792	362.7		
Total	29	14769			

Model Summary

S	R-sq	R-sq (adj)	R-sq (pred)
19.0437	33.70%	28.79%	18.15%

Table 4.

Treatment Grouping Information Using the Tukey Method and 95% Confidence for Site 3D				
Treatment	N	Mean	Grouping	
C	10	68.29	A	
B	10	42.70		B
A	10	39.51		B

Table 5.

Power Analysis of One-Way ANOVA				
Number of Groups	Sample Size	Power	Effect Size	Significance Level
3	10	0.6352	0.5	0.05

Table 6.

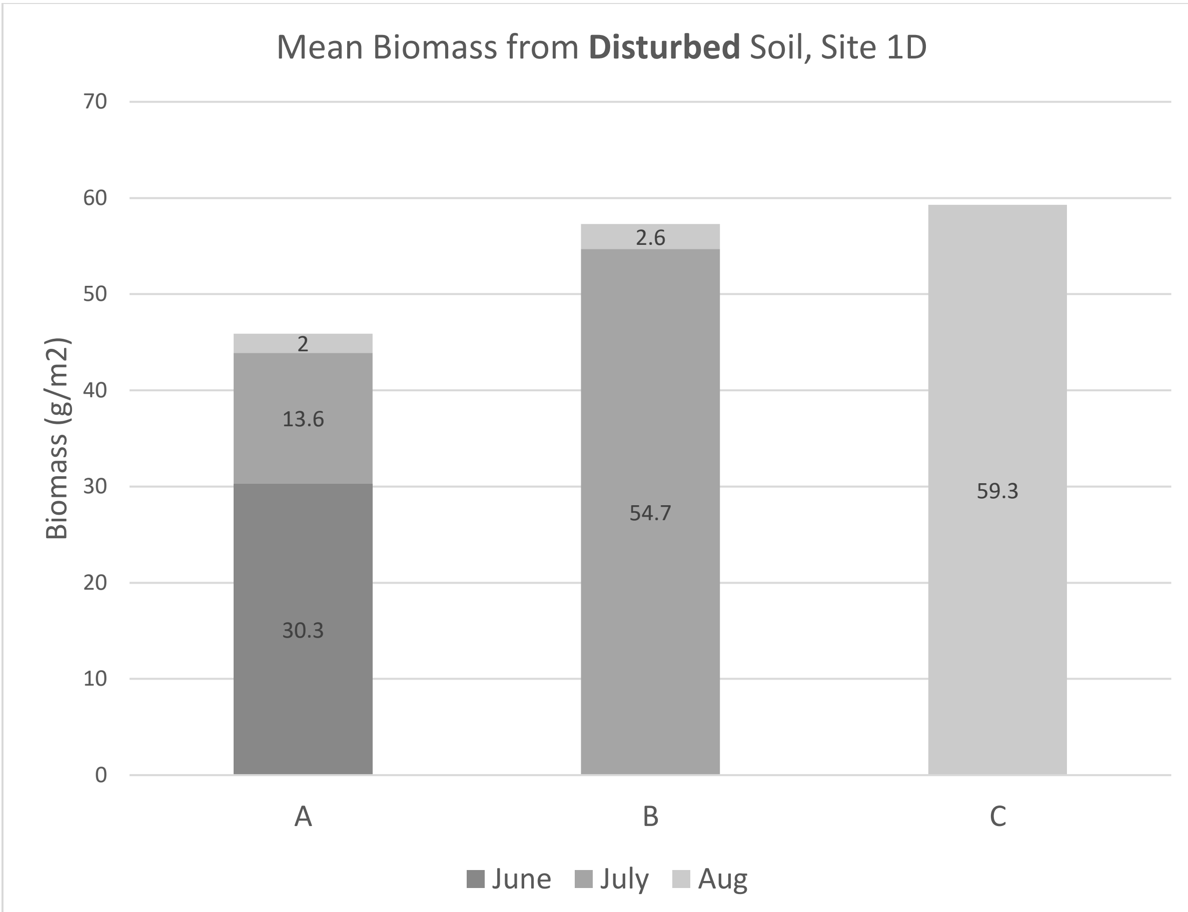

Figure 1.

The average biomass in g/m^2 harvested from Site 1D for the 2015 growing season. Treatment A was clipped three times, treatment B was clipped two times, and treatment C was clipped once at the peak of biomass production for warm season grasses in Kansas. The mean total production of samples A, B, & C for site 1D were 45.9 g/m^2, 57.3 g/m^2, and 59.3 g/m^2. Total biomass production for the site was 162.5 g/m^2. ANOVA test did not show significance with a p-value of 0.389.

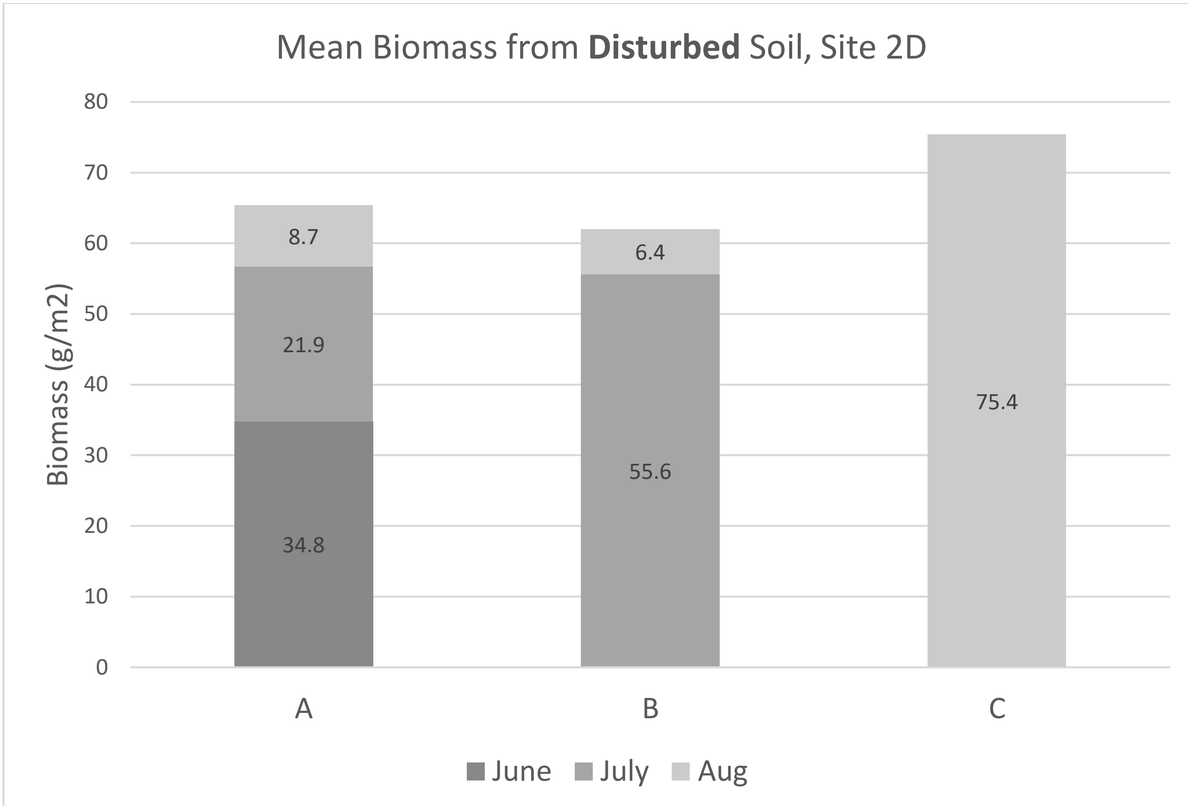

Figure 2.

The average biomass in g/m^2 harvested from Site 2D for the 2015 growing season. Treatment A was clipped three times, treatment B was clipped two times, and treatment C was clipped once at the peak of biomass production for warm season grasses in Kansas. The mean total production of samples A, B, & C for site 2D were 65.4 g/m^2, 62.0 g/m^2, and 75.4 g/m^2. Total biomass production for the site was 202.8 g/m^2. ANOVA test did not show significance with a p-value of 0.372.

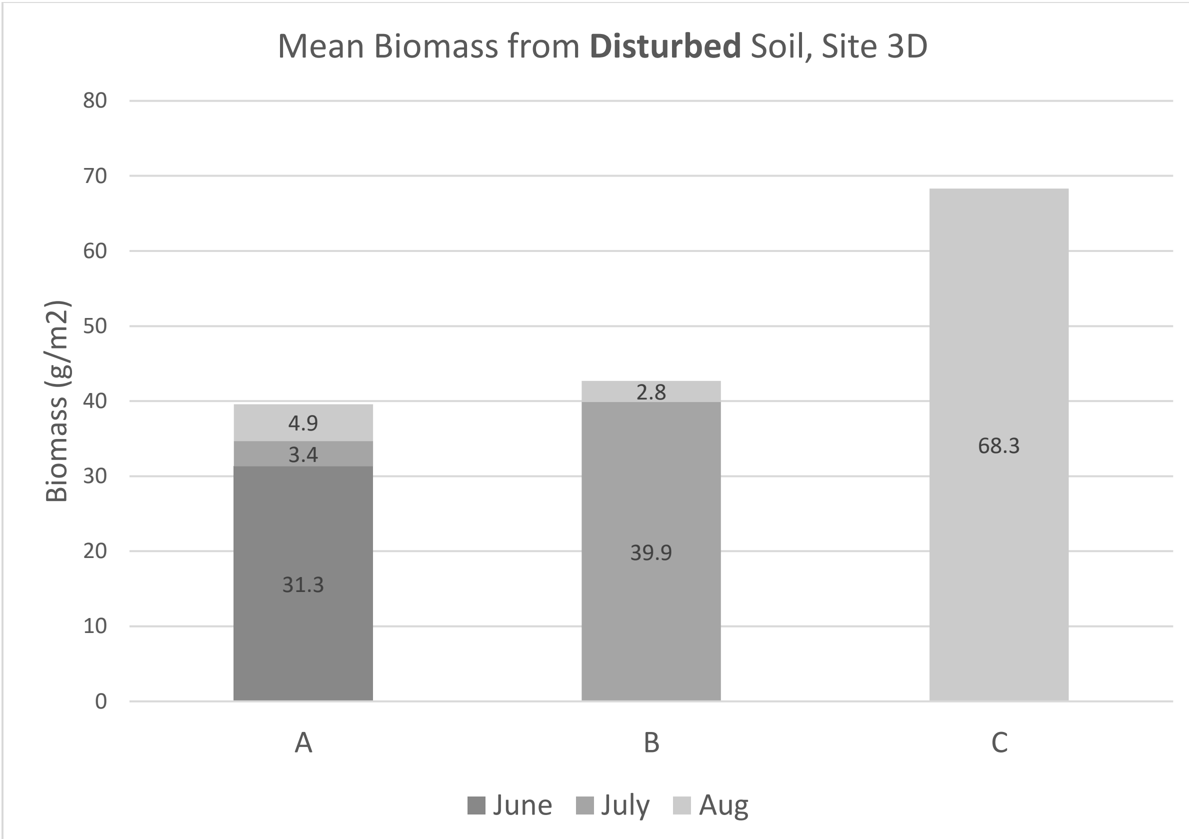

Figure 3.

The average biomass in g/m^2 harvested from Site 3D for the 2015 growing season. Treatment A was clipped three times, treatment B was clipped two times, and treatment C was clipped once at the peak of biomass production for warm season grasses in Kansas. The mean total production of samples A, B, & C for site 3D were 39.6 g/m^2, 42.7 g/m^2, and 68.3 g/m^2. Total biomass production for the site was 150.6 g/m^2. ANOVA test show significance with a p-value of 0.004. Treatments A and B were not significantly different, but C was significantly different from A and B.

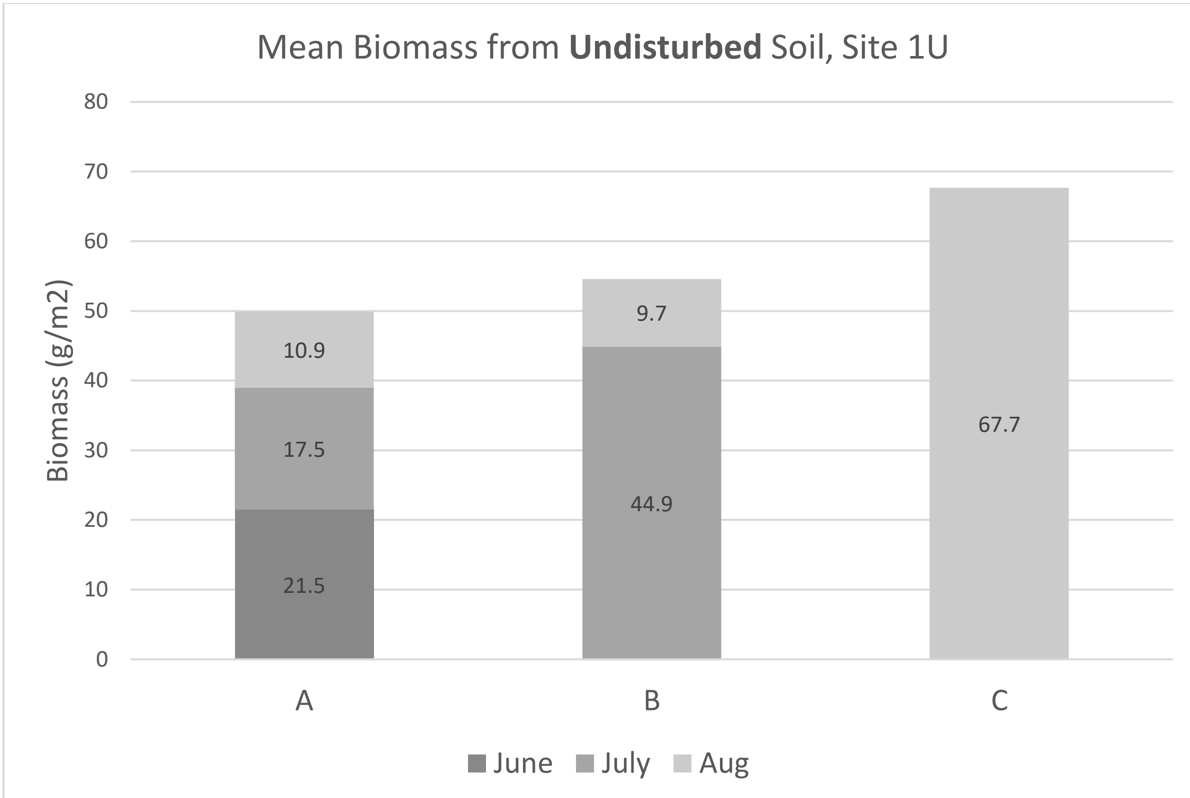

Figure 4.

The average biomass in g/m^2 harvested from Site 1U for the 2015 growing season. Treatment A was clipped three times, treatment B was clipped two times, and treatment C was clipped once at the peak of biomass production for warm season grasses in Kansas. The mean total production of samples A, B, & C for site 1U were 49.9 g/m^2, 54.6 g/m^2, and 67.7 g/m^2. Total biomass production for the site was 172.2 g/m^2. ANOVA test did not show significance with a p-value of 0.175.

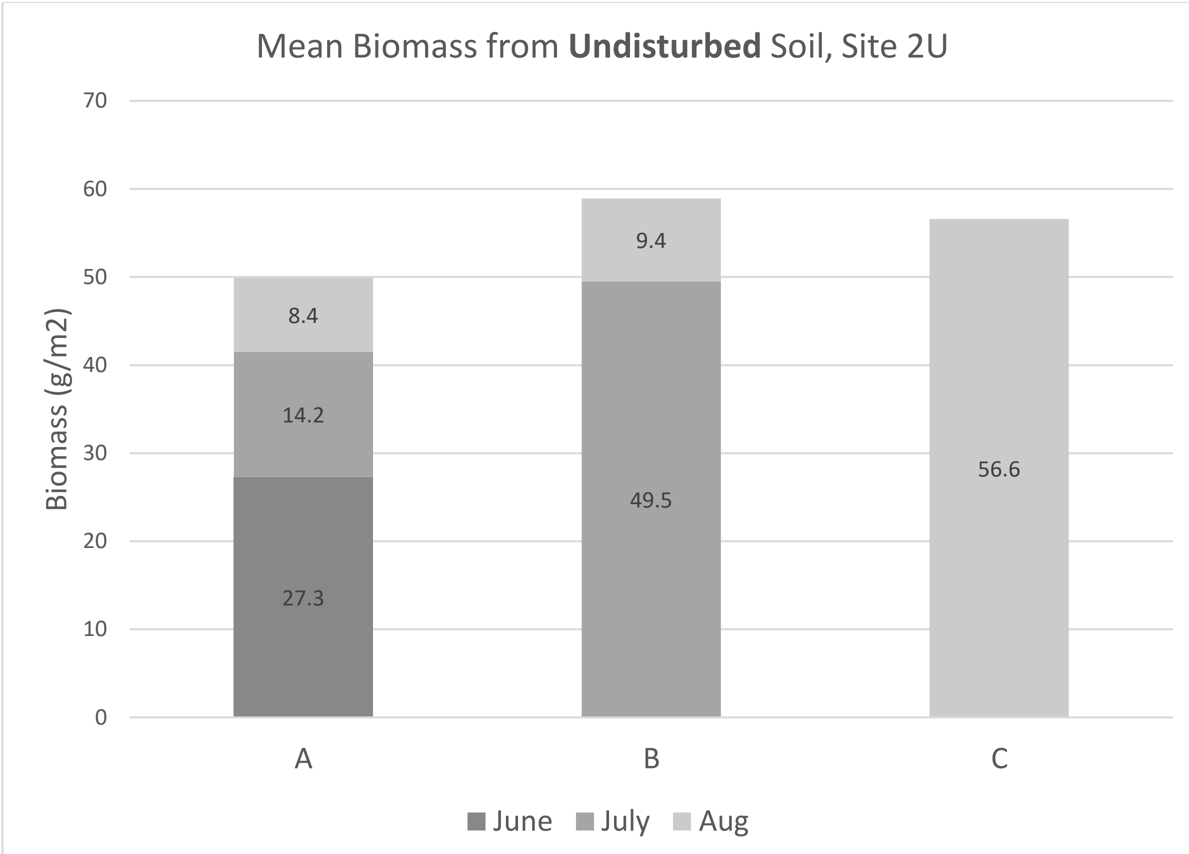

Figure 5.

The average biomass in g/m^2 harvested from Site 2U for the 2015 growing season. Treatment A was clipped three times, treatment B was clipped two times, and treatment C was clipped once at the peak of biomass production for warm season grasses in Kansas. The mean total production of samples A, B, & C for site 3U were 49.9 g/m^2, 58.9 g/m^2, and 56.6 g/m^2. Total biomass production for the site was 165.4 g/m^2. ANOVA test did not show significance with a p-value of 0.253.

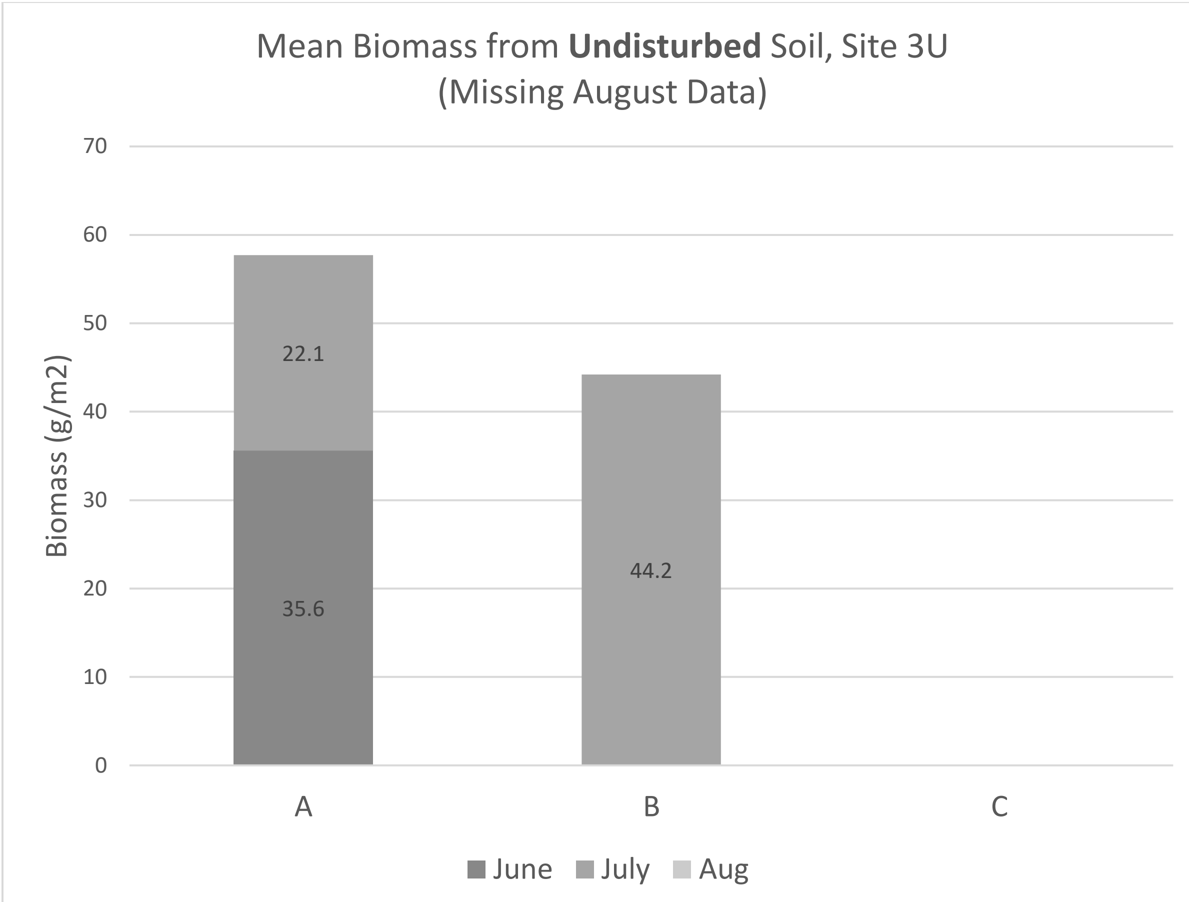

Figure 6.

The average biomass in g/m^2 harvested from Site 3U for the 2015 growing season. All samples for August were not collected due to an unforeseen loss of the grasses in the field prior to collection. This site had an over compensation in production for group A after clipping. The mean total production of samples A and B were 57.7 g/m^2 and 44.2 g/m^2. Total biomass production for the site was 101.9 g/m^2. There was no statistical analysis due to incomplete data.

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