RELATIONSHIP BETWEEN VISUAL OBSTRUCTION READING AND HERBAGE PRODUCTION FOR ECOLOGICAL SITES IN A SEMI-ARID CLIMATE OF THE NORTHERN PLAINS

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Title

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF SCIENCE

ABSTRACT

Woehl, Derek Devonne, M.S., Natural Resources Management, College of Graduate and Interdisciplinary Studies, North Dakota State University, April 2010. Relationship between Visual Obstruction Reading and Herbage Production for Ecological Sites in a Semi-Arid Climate of the Northern Plains. Major Professors: Dr. Kevin K. Sedivec and Dr. Christopher S. Schauer.

A Visual Obstruction Reading (VOR) is an objective non-destructive biomass measurement of height and density made by using a Robel pole. It was used in this study to help determine if a relationship exists between VOR and herbage production on selected ecological sites. The study was conducted within the Little Missouri National Grasslands of western North Dakota and Grand River National Grasslands of north western South Dakota. Three ecological sites: loamy, sandy, and clayey, were stratified within three study blocks comprising 600 km^2, 640 km^2, and 640 km^2. These study blocks were stratified by ecological site with research plots randomly selected among all available areas. Each plot contained two transects that were laid out perpendicular to each other at a length of 150m x 150m with 75 m as the center point in 2007 and 2008, 75m x 75m with 37.5m as the center point in 2009. Herbage production was collected using a 0.178 m^2 frame and VOR's were recorded from the center of the frame prior to clipping. Herbage was clipped to ground level, dried for 48 hr at 110 degrees C, and weighed. Regression analysis was conducted using Proc-Reg procedures of SAS. All ecological sites had a significant ($P \leq 0.05$) correlation between height and weight. The regression models used data derived from the average of samples for each ecological site. These data compared more favorably than comparing individual data points. The adjusted r^2 value for the clayey ecological site was 0.1134, with the model $y = .9671x + 24.62$. The adjusted r^2 value for the loamy ecological site was 0.1701 with the model $y = 1.703x + 17.612$. The adjusted r^2

value for the sandy ecological site was 0.1364 with the model $y = 1.8706x + 20.419$. Although a correlation was found between height and weight for all ecological sites, the regression values did not meet our expectations of a high r^2 value and were no better than 0.519 for the sandy site.

ACKNOWLEDGEMENTS

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INTRODUCTION

Rangeland vegetation in the western Dakotas is a valuable natural resource. The vegetation that grows within the Little Missouri and Grand River National Grasslands provides an important resource to livestock, wildlife and the people that live within these grasslands. Assessment for livestock usage of this resource can help determine best use scenarios for these lands. The visual obstruction reading (VOR) is a tool that was developed to determine the amount of standing crop as it relates to a density measurement (Robel et al. 1970). Clipping is one of the most common methods for determining dry weight of standing crop (Milner and Hughes 1968). Clipping can produce objective measurements of dry weight; however, it is a time consuming destructive sampling method. Non-destructive techniques have proven to be effective in providing accurate estimates of standing crop. These techniques include the biometer (Pearson et al. 1976), Massey grass meter (Holms 1974), Ellinbank pasture meter (Earler and McGowan 1979), and rising plate meter (Michell and Large 1983). Although VOR has been historically used to determine structure for many wildlife species (Higgins 1977, Uresk et al. 1999, Geaumont 2009), its potential to estimate herbage production can offer a fast, cheaper monitoring tool.

Determining a height to weight correlation can help evaluate the effectiveness of the Robel pole technique for predicting herbage production and standing crop. These correlations can help land managers estimate production using models, such as previous studies conducted by Benkobi et al. (2000), Vader (2000), Vermeire and Gillen (2001), and Uresk and Benzon (2007).

In recent years, the VOR technique has garnered interest from the USDA Forest Service for its potential to estimate phytomass from vegetation height or structure (Benkobi et al. 2000). This study was conducted on three distinct regions within the mixed grass prairie in the western Dakotas. Although most previous studies addressed the relationship between VOR height and standing crop, our study objective was to evaluate the relationship between height and weight of phytomass, and evaluate the correlation of VOR measurements to livestock grazing pressure on different ecological sites.

LITERATURE REVIEW

Visual Obstruction Readings

The visual obstruction reading (VOR) is a tool that was developed to determine the amount of standing crop in a height to density measurement for wildlife cover (Robel et al. 1970). Visual obstruction readings are determined using a Robel pole. Robel et al. (1970) was interested in evaluating specific habitat types and comparing those types to the height and density of the surrounding vegetation.

Clipping is one of the most common methods for determining dry weight of standing crop (Milner and Hughes 1968). This method can yield objective measurements of dry weight, however it is time consuming. Non-destructive techniques have proven to be effective in providing accurate estimates of standing crop. Such techniques include the Massey grass meter (Holms 1974) and the rising plate meter, also called a sward (Michell and Large 1983).

Visual obstruction readings have been used to determine structure for many wildlife species (Higgins 1977, Uresk and Benzon et al. 1999, Geaumont 2009). A study conducted for prairie chicken habitat by Hamerstrom et al. (1957) involved the correlation of height:density to determine vegetative cover for nesting birds. Prairie chickens depend on height and density of vegetation more than plant species composition (Hamerstrom et at. 1957).

The study by Hamerstrom et at. (1957) led to the development of a measuring tool that evaluated the height and density of vegetation (Robel et al. 1970). Robel et al. (1970) tested several techniques, including different heights and distances from the measured pole to determine a correlation. They found a reading from a distance of four meters and a height of one meter provided the best *P*-values for the r^2 measurement. In recent years, the VOR technique has garnered interest from USDA Forest Service personal for its potential to estimate herbage production weight from vegetation height or structure (Benkobi et al. 2000, Crowder et al. 2004, Limb et al. 2007). More recently, the USDA Forest Service has been interested in predicting herbage production, or phytomass from the VOR height.

Many wildlife biologists have used VOR since the development of the Robel pole. Most of the research using the Robel pole tested different management techniques on wildlife habitat and upland nesting birds (Kobriger 1981, Sedivec 1994, Messmer 1985, Higgins 1986, Grosz 1988, Hertel 1987, Grosz 1988, Sedivec 1989, Uresk and Benzon 2007, Uresk and Juntti 2008, Geaumont 2009). Geaumont (2009) conducted a study on pheasant and duck nesting cover in post Conservation Reserve Program land in western North Dakota. He found a successful nesting rate of 57% for the area that had a cover of 2.5 dm on 50% or more of the land. Rumble and Flake (1983) studied different variables of vegetative height at the edge of wetlands to determine cover for waterfowl species. Many duck species showed a positive correlation between nesting and vegetation associated with VOR readings at wetland sites. Wetlands with a high amount of shoreline vegetation were more desirable for breeding and had a higher brood count for waterfowl species.

Paine et al. (1996) studied the effect of livestock grazing on upland nesting birds. They found three different stocking rates were not different in upland nesting bird survival at 25%. Higgins and Barker (1982) conducted a study that utilized changes in height of a variety of seeded areas to determine VOR. Higgins (1986) also conducted a study using a Robel pole to determine preferences of different shrub communities by various bird coveys. He determined that higher vegetative areas had a higher bird density and increased bird species diversity.

Height:weight Correlations

Many studies have been conducted testing the height:weight correlation on individual plant species and landscapes; however, little research exists testing height:weight correlations of different ecological range sites, plant communities or phytomass. Uresk and Benzon (2007) and Vermeire and Gillen (2001) found a strong height:weight correlation for standing crop by vegetation type and ecological site in Nebraska, South Dakota, Montana and New Mexico in preliminary U.S. Forest Service studies using the VOR. However, Volesky et al. (1999) found conflicting results with height using VOR and weight. Volesky et al. (1999) tested a leaf area index and visual obstruction on upland ecological sites in the Nebraska sand hills and found a poor correlation with forage production on the ecological sites studied in their area.

Heady (1950) defined the height:weight correlation as "a term designating the percentage of the total weight of a bunch of a grass, often at inch-intervals above the soil when the leaves of a fully grown plant are held in an upright position and wrapped against the culms into a tight, somewhat conical bundle. Heady (1950) also defined height:weight in terms of individual species in that "it is based on the premise that the weight of plant materials in relation to the height at which they are taken remains constant with individuals of a species that have approximately the same height."

There have been many studies testing the correlation between the height and weight of many individual plant species on very distinct ecological sites (Crafts 1938, Lommasson and Jensen 1938, 1943, McDougald and Platt 1976, Mitchell et al. 1993, Vader 2000, Vermeire and Gillen 2001). Vader (2000) found a correlation between height and weight on different ecological sites; however the correlation had a better regression values on sites with higher species evenness and homogeneity. Vader (2000) found sites with the best fit were sites high in Kentucky bluegrass presence and of mid topographic location. Vermeire and Gillen (2001) also found a stronger correlation with VOR height and standing crop when only one VOR location was collected within a clipped plot. They concluded this method reduced the risk of an individual forb or shrub exaggerating the VOR height on low producing areas.

Benkobi et al. (2000) and Uresk et al. (1999) focused on vegetative type and incorporated the entire plant community for a height to weight correlation. They found a strong correlation between height and weight when incorporating the entire plant community, especially when the study focused on a homogenous plant community. These findings are also similar to a study conducted by Reid and Pickford (1941) who reported a correlation between height and weight of mountain bunch fescue (*Festuca virdula*). However, they stated that the height to weight model was only a good tool for estimation of species utilization. Likewise, there have been other studies that found no correlation between height and weight due to many external factors. These factors include heterogeneity of species on a site, wildlife and livestock disturbances, and drastic change of ecological site. Heady (1950) acknowledged many of these variables and factors that lead to the height to weight correlation which was used to estimate utilization. He concluded that height to weight was best determined for consistent ecological sites and homogeneity of species.

STUDY AREA

This study was conducted on the Dakota Prairie Grasslands within the Little Missouri National Grassland (LMNG) of North Dakota and Grand River National Grassland (GRNG) of South Dakota (Figure 1). The Grand River National Grassland is managed by the USDA Forest Service Grand River Ranger District. The Little Missouri National Grassland is managed by the USDA Forest Service Medora Ranger District (MRD) to the south and McKenzie Ranger District (McRD) to the north. Data were collected in allotment management units on different ecological sites in the GRNG, MRD and McRD.

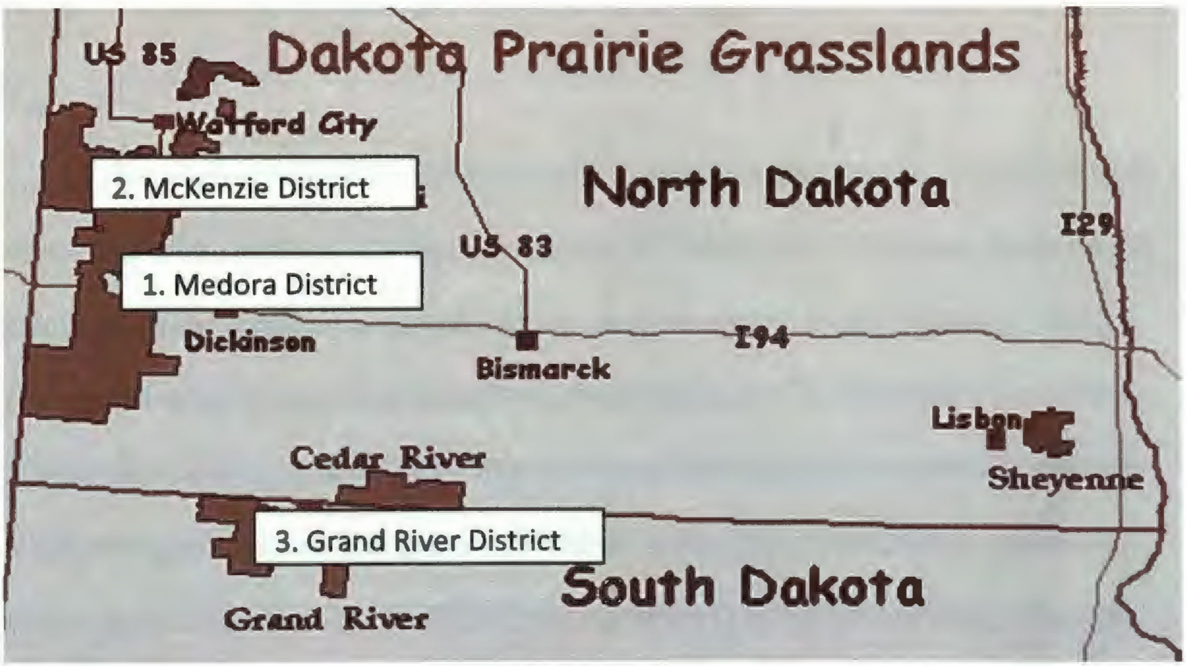

Figure 1. Location of the Little Missouri National Grasslands Medora Ranger District (1), McKenzie Ranger District (2) and Grand River Ranger District (3) in North and South Dakota.

The GRNG is located in northwestern South Dakota west of Lemmon and south of Hettinger, North Dakota. The study area encompasses approximately 20,000 hectares. The area is characterized by rolling hills with isolated rock outcroppings. Mean precipitation is 394 mm with 70% or more occurring during the April to September growing season (NDAWN 2010).

The MRD and McRD are located in west-central North Dakota. The study areas in both ranger districts are approximately 60,000 hectares. Both districts are characterized by rolling prairie with numerous badland outcroppings. Mean precipitation in the MRD is 422 mm with 70% or more occurring during the growing season. Mean precipitation in the McRD is 366 mm with 75% or more occurring during the growing season (NDAWN 2010).

Vegetation

The vegetation on the LMNG is classified as mixed grass prairie, intermixed with short grass prairie badland outcrops (Barker and Whitman 1988). Common plants found within MRD and McRD are western wheatgrass *(Pascopyron smithii* [Rydb. A. Love], green needlegrass (*Nassella viridula* [Trin.] Barkworth), needle and thread (*Hesperostipa comata* [Trin. & Rupr.] Barkworth), little bluestem (*Schizachyrium scoparium* [Michx.] Nash), blue grama (*Bouteloua gracilis* [Willd. ex Kunth] Lag. ex Griffiths), and sedges (*Carex spp.*). Vegetation on the GRNG was classified as mixed grass prairie. Common plants include western wheatgrass, blue grama, needlegrasses, sedges, and seeded areas of crested wheatgrass (*Agropyron cristatum* [L.] Gaertn.). The United States Department of Agriculture PLANTS database was used as the primary reference for plant species nomenclature in this document (USDA, NRCS 2010).

Clayey Ecological Site

The clayey ecological sites were found within the rolling soft shale plain in Major Land Resource Areas 54 and 58 (USDA, NRCS 2008). The resource site is considered to have a continental climate, defined as cold winters and hot summers. The average precipitation ranges from 358 mm to 457 mm per year. The common features of soils in this site are silty clay to clay textured subsoil. The slopes of this ecological site are 0 to 25 percent and moderately well to well-drained soils. The silty clay loam to loam surface layer is 12 to 35 cm thick. The soils for this site have moderately slowly to slow infiltration rates. When dry they can crack and when wet swell. This soil type shows slight to no evidence of rills or wind scoured areas; however, they are susceptible to water erosion. Common plants found within the clayey ecological site are western wheatgrass, green needlegrass, needle and thread, little bluestem, blue grama and sedges.

Loamy Ecological Site

The loamy ecological sites occur on gently undulating to rolling sedimentary uplands in Major Land Resource Areas 54 and 58 (USDA, NRCS 2008). This resource site has a continental climate, defined as cold winters and hot summers. The average precipitation ranges from 361 mm to 464 mm per year. The common features of soils in this site are silt loam to clay loam textured subsoil. The slopes of this ecological site are 0 to 20 percent and soils moderate to well-drained. The silt loam to loam surface layer is 12 to 35 cm thick. The soils for this site have moderate infiltration rates with risk of rills and gullies if vegetative cover is not adequate. Common plants found within the loamy ecological site are western wheatgrass, green needlegrass, needle and thread, little bluestem, blue grama and sedges.

Sandy Ecological Site

The sandy ecological sites occur on gently undulating to rolling sedimentary uplands and found in Major Land Resource Areas 54 and 58 (USDA, NRCS 2008). This resource site is considered to have a continental climate, defined as cold winters and hot summers. The average precipitation ranges from 361 mm to 464 mm per year. The common features of soils are sand to fine sandy loam. The slopes are 2 to 20 percent and soils moderate to well-drained. The fine sandy loam and sandy loam surface layer is 12 to 35 cm thick. Common plants found on the sandy ecological sites are prairie sandreed (*Calamovilfa longifolia* (Hook.) Scribn.), little bluestem, blue grama and sedges.

METHODS AND DESIGN

The methods and design for this study were developed cooperatively with USDA Forest Service, the Grazing Associations of the Little Missouri Grassland and Grand River National Grassland, and North Dakota State University. The study plots were conducted from June to August and selected by stratifying each ranger district by ecological site and 100 m buffer areas (fence, roads, water, and reseeded pastureland). The plots were 150 x 150 m in 2006-2008 and 75 x75 m in 2009. The plots were grouped in blocks which were determined by the US Forest Service for management. A block is several pastures that constitute a single management unit. Plot size within those blocks were reduced in 2009 based on sample size adequacy tests that showed data output would be similar at the $P \leq 0.05$ level. The plots were placed perpendicular on the four cardinal directions with the center point located using a Trimble GPS unit. A soil pit was dug on each ecological site to verify the underlying soils.

Visual obstruction readings were collected using a modified Robel pole marked at 0.254 dm increments, with measurements collected in the center of the frame prior to clipping. Readings were taken at each station from a distance of four meters and a height of one meter in all four cardinal directions to determine mean height of standing crop (Robel et al. 1970). Once the VOR was collected, the 0.178 m^2 frame was clipped for phytomass to ground level. The 0.178 m^2 frame was used because it is standardized for many land managing agencies. The degree of disappearance was estimated on a scale of 1-5 at increments of 20% disappearance (Anderson and Currie 1973, Taylor and Lacy 1987, Johnson et al. 1997). During the first years of collection (2007-2008), the VOR/clipping stations were located at 30, 60, 90 and 120 meters on both the N-S transects and E-W transect. During the 2009 field season, the clipping stations were located at 30, 60 and 90 meter on both the N-S transects and E-W transects. The vegetation from the clipped plot was separated by current year's growth (Phytomass) and litter (when both combined they predict total standing crop).

VOR and Phytomass was determined for each plot within the block and a mean VOR and phytomass for the entire block. The VOR heights and phytomass weights were tested for correlation using a linear regression model where weight was the dependent variable "y" and height the independent variable "x". "x" represents height in centimeters with "y" calculated by multiplying the model output by 44.5 to predict kg/ha.

Linear regression models were determined for the clayey, loamy and sandy ecological sites for a vegetative height:weight relationships using a standard linear regression model (Sokal and Rohlf 1981). The r^2 value was adjusted (r^2) to determine best fit model (Sokal and Rohlf 1981). Standard errors were calculated for the model. Outliers were identified by their "undo" influence on the regressions. Outliers constituted only 1% of the samples. Equation models were developed for linear relationships when regressions were significant ($P \leq 0.05$). An equation model was determined for each ecological site by combining all grassland study locations and determining best fit r^2 value by block and plot. The block provided the best fit, so regression models were determined for each ecological site by location using the block data. Standard errors of the residuals were determined for all regressions while standard errors of the predicted weights were determined for linear correlations.

Each transect was classified by degree of livestock forage disappearance (0-20% - 1, 20-40% - 2, 40-60% - 3, 60-80% - 4, 80-100% - 5) using techniques described by

Anderson and Currie (1973), Taylor and Lacy (1987), and Johnson et al. (1997). Transects classified as 0 to 20 % disappearance were none to lightly grazed, 20 to 40 % disappearance moderately grazed, 40 to 60 % disappearance full use, 60 to 80 % disappearance close use, and 80 to 100 % disappearance severe use. Only survey blocks conducted from 24 June through 24 August were used in this data analysis to best represent peak herbage production.

Within each ecological site, mean VORs and phytomass were determined for each livestock grazing disappearance category and analyzed using a General Linear Model of SAS to determine differences in VOR and phytomass among each category. A *P*-value of 0.05 was used to determine if a significant difference occurred.

RESULTS

Ecological Site

The clayey, loamy and sandy ecological sites were analyzed using all combined study areas for linear regression testing VOR height and phytomass. The r^2 using the linear regression model was less than 0.20 for all ecological sites. The loamy site had the best fit while the clayey least fit for predicting phytomass weight from VOR height. The loamy ecological site was the highest producing ecological site, on average in the study (Table 1). The clayey and sandy ecological sites were similar in herbage production at 1,316 kg/ha and 1369 (Tables 2 and 3).

Table 1. Average annual herbage production and mean Visual Obstruction Reading (VOR) for all loamy ecological sites by degree of disappearance category on the Little Missouri and Grand River National Grasslands in 2007 through 2009.

Degree of Disappearance Category[1]	Number of Plots	Average Kg/Ha	SE	Mean VOR (cm)	SE
1	763	1482	830.4	6.00	4.39
2	212	1389	1011.4	6.05	4.64
3	77	655	329.5	2.11	1.80
4	16	680	418.5	3.18	1.31
5	0	0	0.0	0.00	0.00

[1] 1 represents 0 to 20 % none to light use disappearance, 2 represents 20 to 40 % moderate use disappearance, 3 represents 40 to 60 % full use disappearance, 4 represents 60 to 80 % close use disappearance, and 5 represents 80 to 100 % severe use disappearance.

Loamy

The r^2 using the linear regression model for loamy ecological site was 0.156 and 0.164 using all plots and blocks (the average of all plots within a blocks), respectively, with a significant correlation ($P \leq 0.05$) between VOR height and phytomass. The predicted model using the blocks for the loamy ecological site was $y = 1.703x + 17.612$, where x is height in centimeters and y equals the model output multiplied by 44.5 kg/ha (Figure 2). The predicted model from using all individual plots for the loamy ecological site was $y = 1.3691x + 18.722$, where x is height in centimeters and y equals the model output multiplied by 44.5 kg/ha (Figure 3). Mean herbage production for all loamy ecological sites was 1,482 kg/ha and similar to production on the clayey ecological site.

Table 2. Average annual herbage production and mean Visual Obstruction Reading (VOR) for all clayey ecological sites by degree of disappearance category on the Little Missouri and Grand River National Grasslands in 2007 through 2009.

Degree of Disappearance Category[1]	Number of Plots	Average Kg/Ha	SE	Mean VOR (cm)	SE
1	427	1316	707.6	5.73	5.68
2	84	793	344.3	4.89	4.46
3	70	761	416.6	3.18	2.76
4	8	685	325.8	3.25	1.04
5	0	0	0.0	0.00	0.00

[1] 1 represents 0 to 20 % none to light use disappearance, 2 represents 20 to 40 % moderate use disappearance, 3 represents 40 to 60 % full use disappearance, 4 represents 60 to 80 % close use disappearance, and 5 represents 80 to 100 % severe use disappearance.

Table 3. Average annual herbage production and mean Visual Obstruction Reading (VOR) for all sandy ecological sites by degree of disappearance category on the Little Missouri and Grand River National Grasslands in 2007 through 2009.

Degree of Disappearance Category[1]	Number of Plots	Average Kg/Ha	SE	Mean VOR (cm)	SE
1	252	1369	859.7	5.19	3.55
2	83	789	316.0	3.08	2.09
3	0	0	0.0	0.00	0.00
4	0	0	0.0	0.00	0.00
5	0	0	0.0	0.00	0.00

[1] 1 represents 0 to 20 % none to light use disappearance, 2 represents 20 to 40 % moderate use disappearance, 3 represents 40 to 60 % full use disappearance, 4 represents 60 to 80 % close use disappearance, and 5 represents 80 to 100 % severe use disappearance.

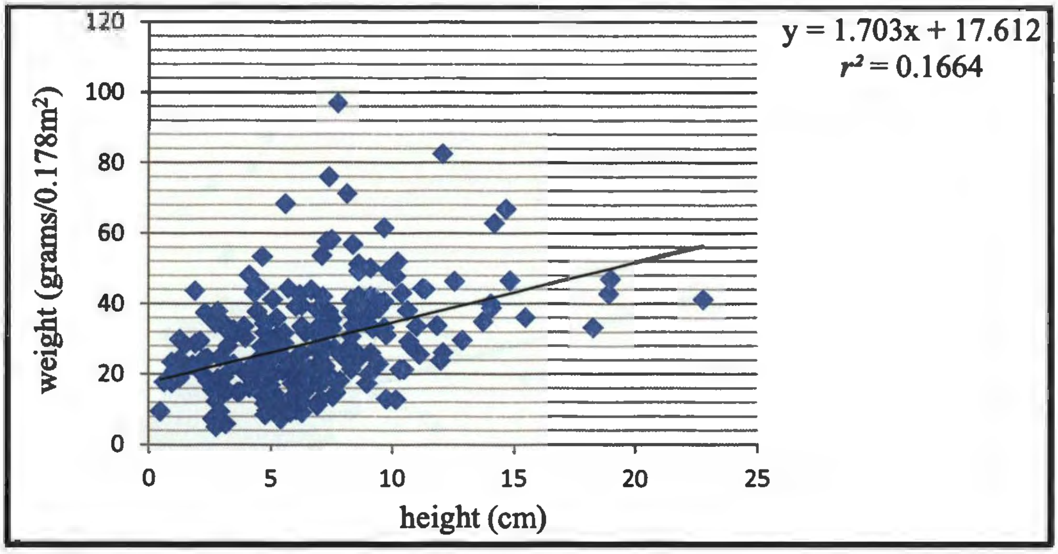

Figure 2. Linear regression model for the loamy ecological site using the blocks (mean for all individual plots within each block) for all loamy sites collected on the Little Missouri and Grand River National Grasslands in 2007 through 2009.

Clayey

The clayey ecological site had the lowest r^2 value among the three ecological sites. The r^2 using a linear regression model from clayey ecological site was 0.128 and 0.1031 for all plots and blocks (the average of all plots within a blocks), respectively, with a significant correlation ($p \leq 0.05$) between VOR height and phytomass. The predicted model from the blocks for the clayey ecological sites was y = 1.2493x + 22.775 (Figure 4) and from the individual plots y = 0.9671x + 24.62 (Figure 5), where x is height in centimeters and y equals the model output multiplied by 44.5 kg/ha. Mean herbage production for all clayey ecological sites was 1,479 kg/ha.

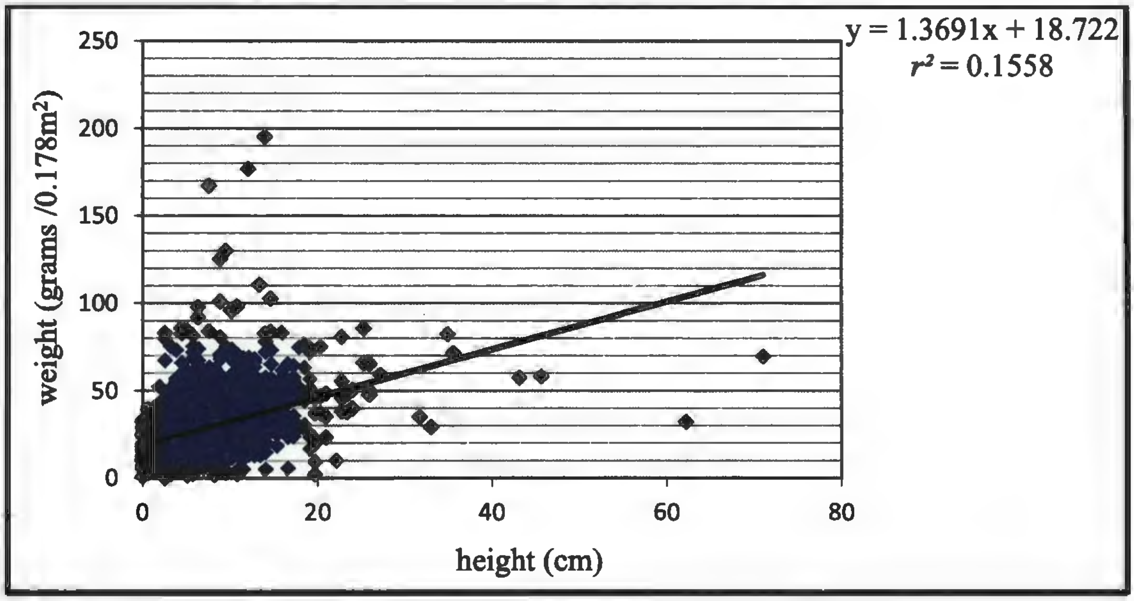

Figure 3. Linear regression model for the loamy ecological site using the individual plots for all loamy sites collected on the Little Missouri and Grand River National Grasslands in 2007 through 2009.

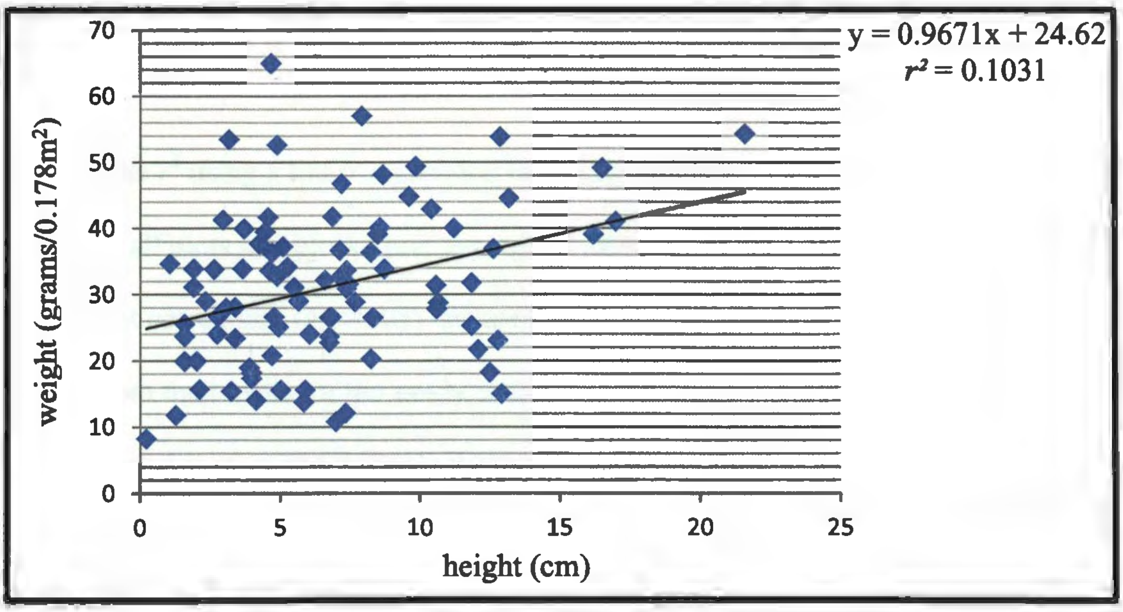

Figure 4. Linear regression model for the clayey ecological site using the blocks (mean for all individual plots within each block) for all clayey sites collected on the Little Missouri and Grand River National Grasslands in 2007 through 2009.

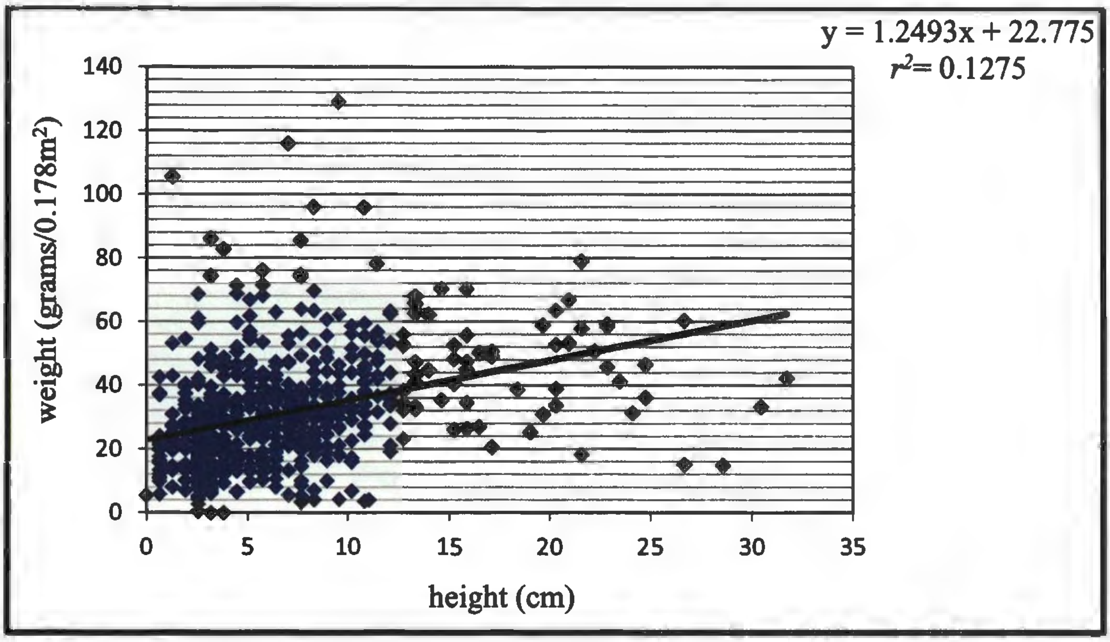

Figure 5. Linear regression model for the clayey ecological site using the individual plots for all clayey sites collected on the Little Missouri and Grand River National Grasslands in 2007 through 2009.

Sandy

The r^2 using a linear regression model for sandy ecological site was 0.151 and 0.128 for all plots and blocks (the average of all plots within a blocks), respectively, with a significant correlation ($P \leq 0.05$) between VOR height and phytomass. The predicted model from the blocks for the sandy ecological site was y = 1.2493x + 22.775, where x is height in centimeters and y equals the model output multiplied by 44.5 kg/ha (Figure 6). The predicted model from the linear regression on the individual plots for the sandy ecological site was y = 1.6264x + 20.3, where x is height in centimeters and y equals the model output multiplied by 44.5 kg/ha (Figure 7). The sandy ecological site produced the greatest amount of herbage among the three ecological sites. Mean herbage production for all sandy ecological sites was 1,649 kg/ha.

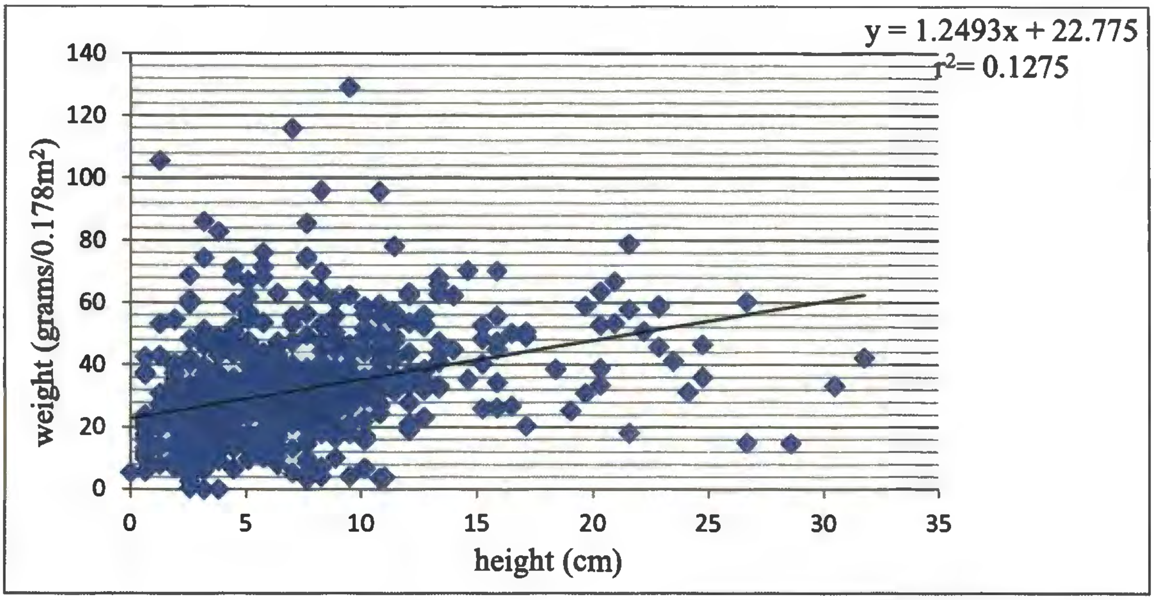

Figure 6. Linear regression model for the sandy ecological site using the blocks (mean for all individual plots within each block) for all sandy sites collected on the Little Missouri and Grand River National Grasslands in 2007 through 2009.

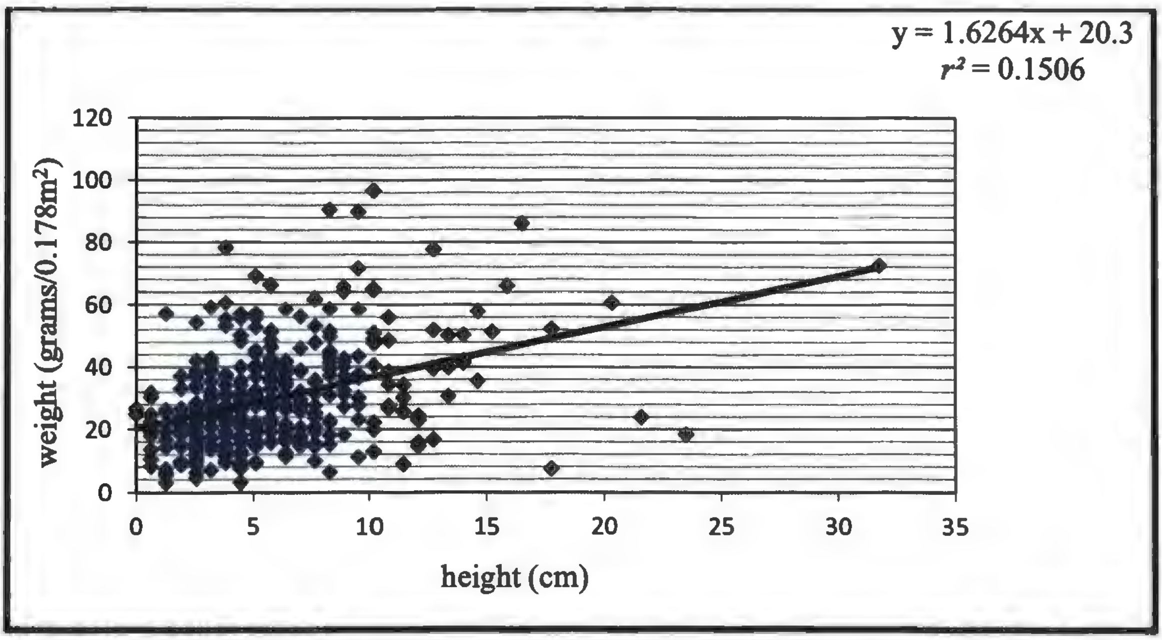

Figure 7. Linear regression model for the sandy ecological site using the individual plots for all sandy sites collected on the Little Missouri and Grand River National Grasslands in 2007 through 2009.

Height:Weight Correlations

<u>Grand River National Grasslands</u>

Clayey, loamy and sandy ecological sites for the Grand River National Grasslands (GRND) were evaluated to determine if a correlation between VOR height and phytomass occurs in a mixed grass prairie of northwestern South Dakota. A significant correlation ($P \leq 0.05$) occurred for all ecological sites and the r^2 using a linear regression model was similar for each ecological site. The r^2 for the loamy ecological site was 0.4158 (Figure 8). The r^2 value was highest on the clayey sites at 0.4403 (Figure 9) and lowest on the sandy site at 0.3946 (Figure 10).

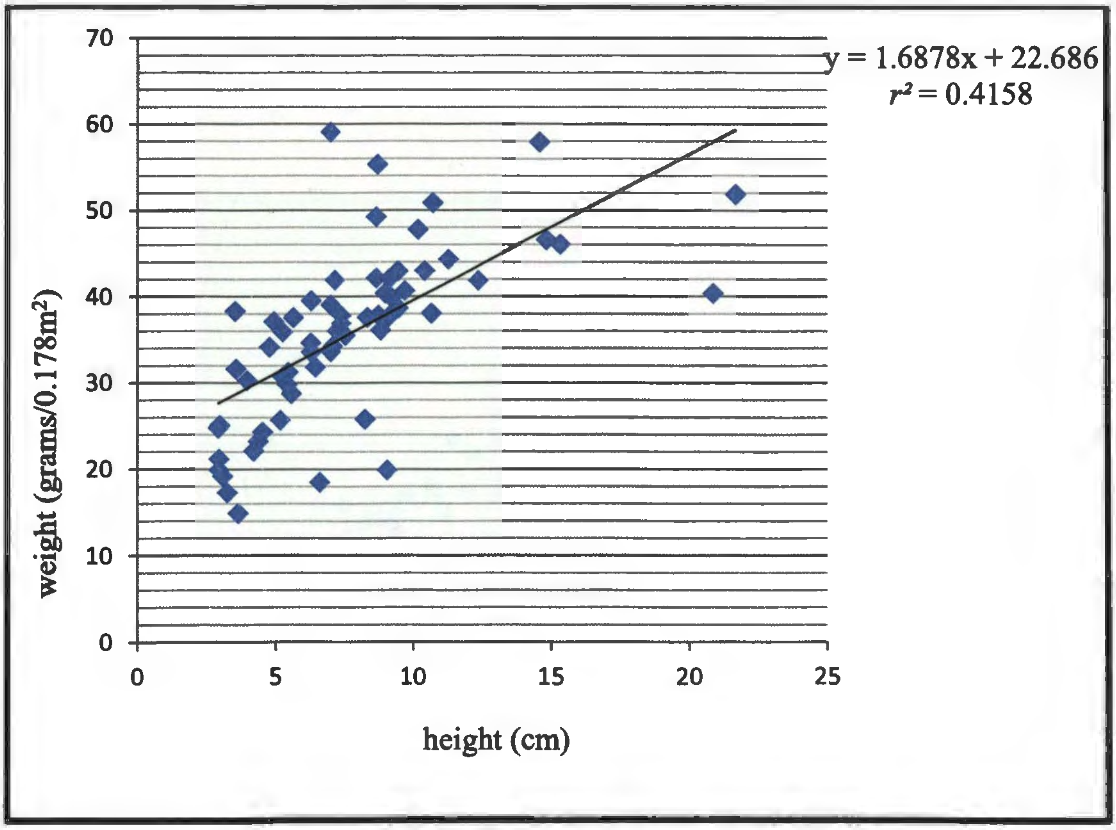

Figure 8. Linear regression model for the loamy ecological site using the block (mean for all individual plots within each block) collected on the Grand River National Grasslands in 2007 through 2008.

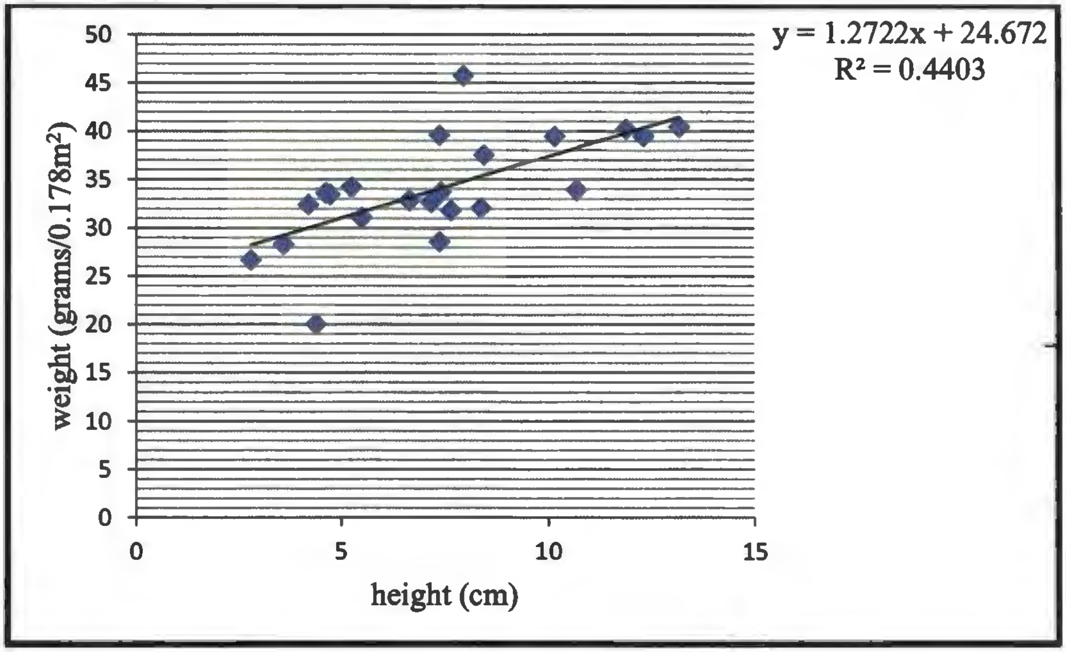

Figure 9. Linear regression model for the clayey ecological site using the block (mean for all individual plots within each block) collected on the Grand River National Grasslands in 2007 through 2008.

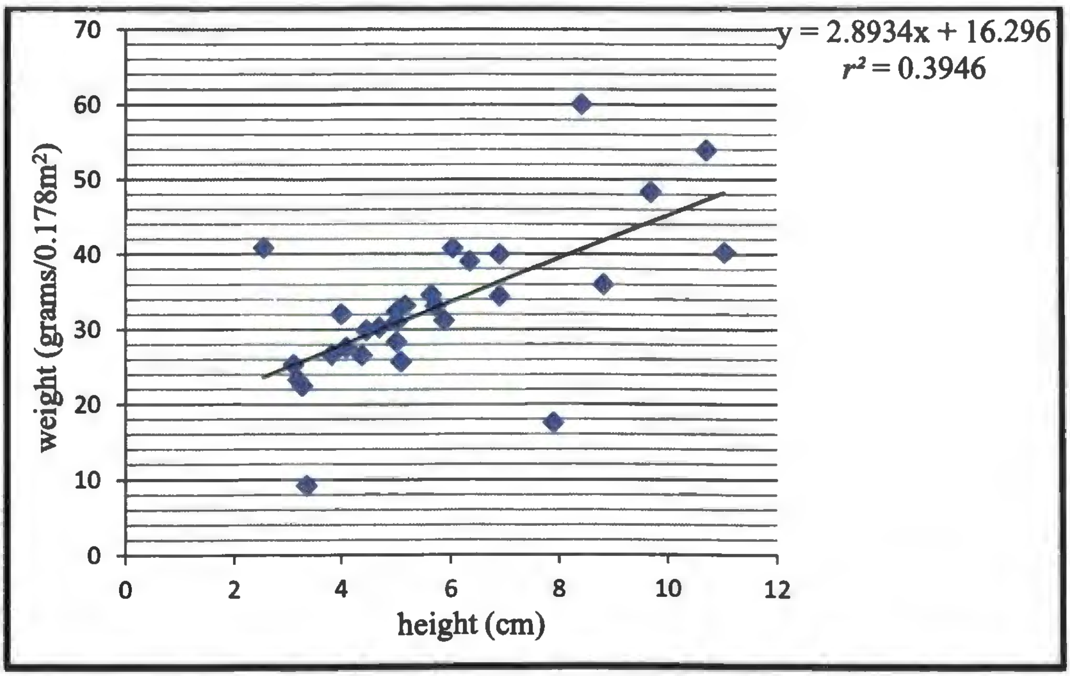

Figure 10. Linear regression model for the sandy ecological site using the block (mean for all individual plots within each block) collected on the Grand River National Grasslands in 2007 through 2008.

Little Missouri National Grasslands - McKenzie Ranger District

Clayey, loamy and sandy ecological sites for the LMNG - McRD were evaluated to determine if a correlation between VOR height and phytomass occurs in a mixed grass prairie of west-central North Dakota. A significant correlation ($p \leq 0.05$) occurred for all ecological sites and the r^2 using a linear regression model was similar for each ecological site (Figures 11, 12, and 13). All ecological sites had a poor regression fit for a height:weight correlation ($r^2<0.05$).

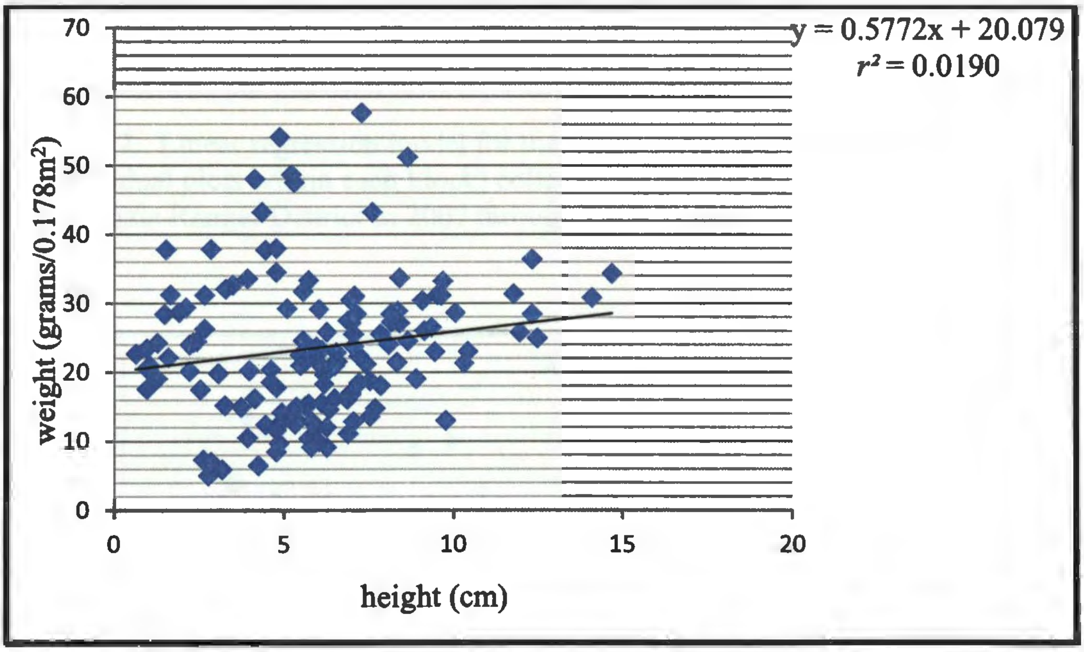

Figure 11. Linear regression model for the loamy ecological site using the block (mean for all individual plots within each block) collected on the Little Missouri National Grasslands – McKenzie Ranger District in 2007 through 2009.

The sandy ecological site had the lowest regression fit for a height:weight correlation on the McRD. The r^2 for the sandy ecological site was 0.0230 (Figure 12). The linear regression model for the sandy site was $y = 0.7734x + 23.107$, where x is height in centimeters and y equals the model output multiplied by 44.5 kg/ha.

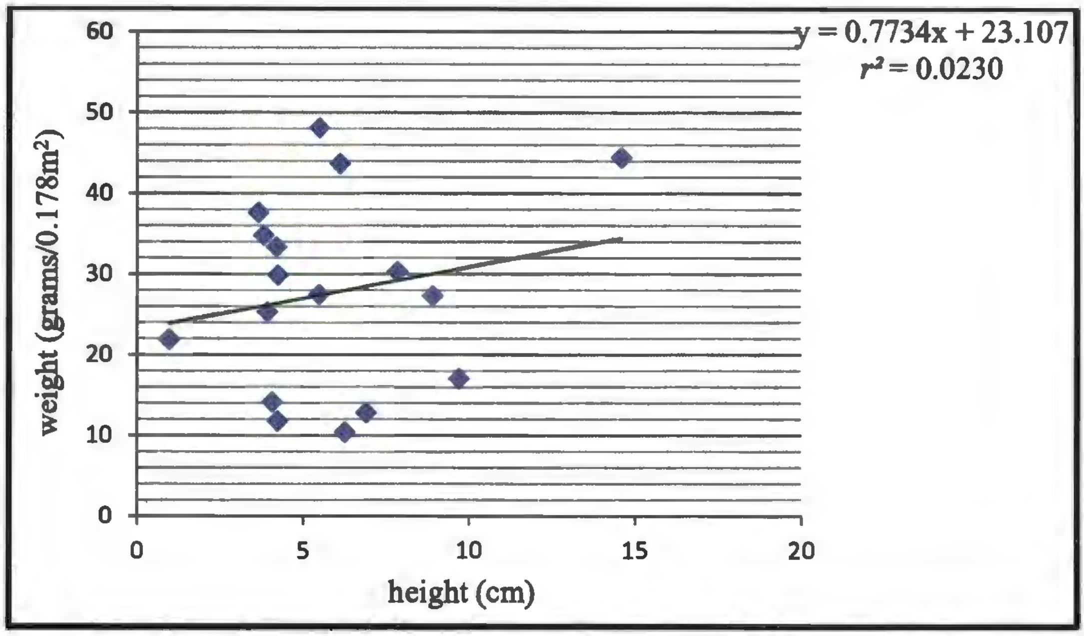

Figure 12. Linear regression model for the sandy ecological site using the block (mean for all individual plots within each block) collected on the Little Missouri National Grasslands – McKenzie Ranger District in 2007 through 2009.

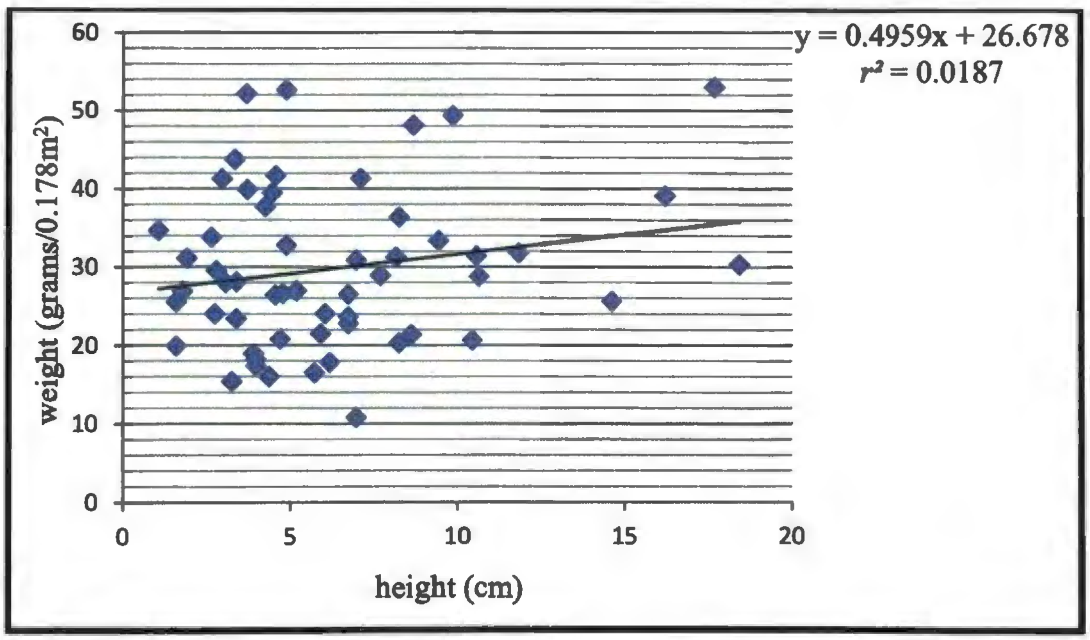

Figure 13. Linear regression model for the clayey ecological site using the block (mean for all individual plots within each block) collected on the Little Missouri National Grasslands – McKenzie Ranger District in 2007 through 2009.

Little Missouri National Grasslands - Medora Ranger District

Clayey, loamy and sandy ecological sites for the LMNG - MRD were evaluated to determine if a correlation between VOR height and phytomass occurs in a mixed grass prairie of southwestern North Dakota. A significant correlation ($p \leq 0.05$) occurred for all ecological sites and the r^2 using a linear regression model was similar for each ecological site. The loamy ecological site had the best regression fit for a height:weight correlation; however, the r^2 was only 0.2733 (Figure 14). The linear regression model for the loamy site was $y = 0.9249x + 13.857$, were x is height in centimeters and y equals the model output multiplied by 44.5 kg/ha.

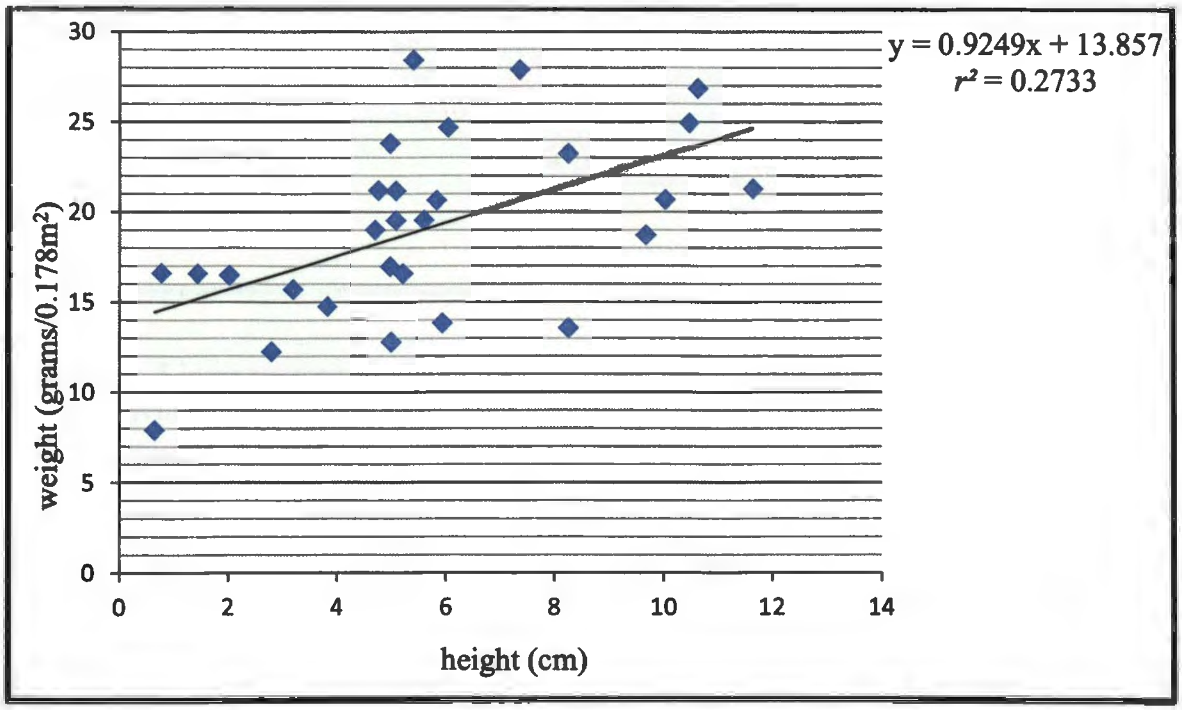

Figure 14. Linear regression model for the loamy ecological site using the block (mean for all individual plots within each block) collected on the Little Missouri National Grasslands – Medora Ranger District in 2008 and 2009.

The clayey ecological site on the MRD had a very poor regression fit for a height:weight correlation. The r^2 for the clayey ecological site was 0.0439 (Figure 15). The linear regression model for the clayey site was y = 0.5347x + 14.244, were x is height in centimeters and y the model output multiplied by 44.5 kg/ha.

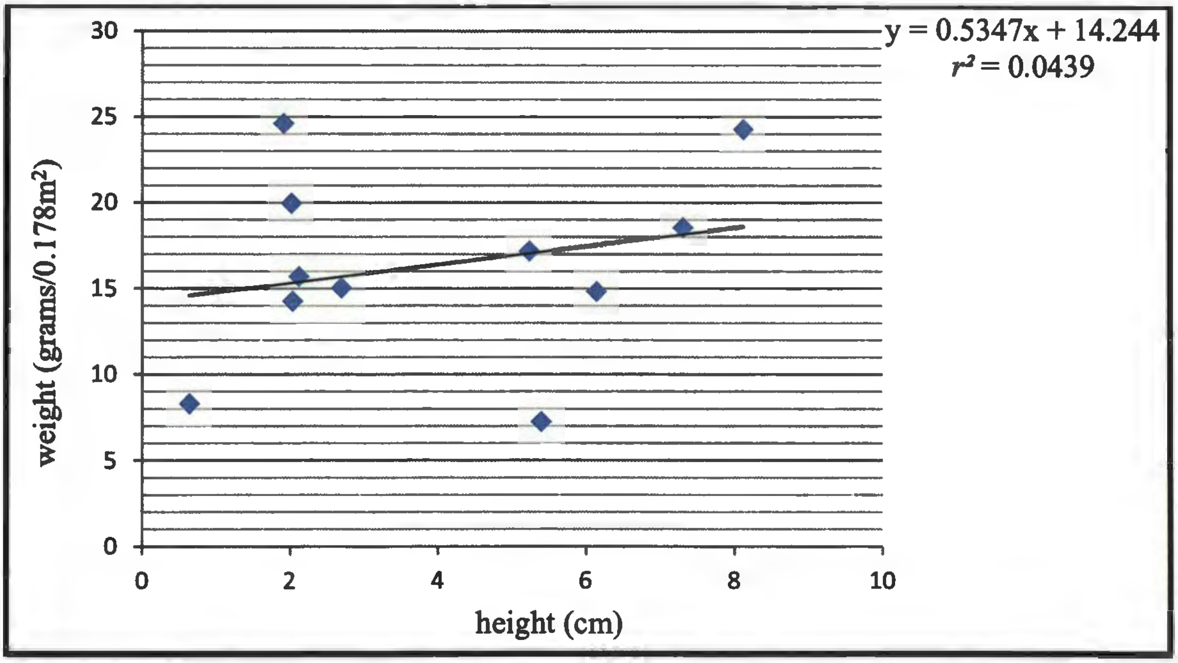

Figure 15. Linear regression model for the clayey ecological site using the block (mean for all individual plots within each block) collected on the Little Missouri National Grasslands – Medora Ranger District in 2008 and 2009.

The sandy ecological site had the lowest regression fit for a height:weight correlation on the MRD. The r^2 for the sandy ecological site was 0.1064 (Figure 16). The linear regression model for the sandy site was y = 0.7734x + 23.107, were x is height in centimeters and y the model output multiplied by 44.5 kg/ha.

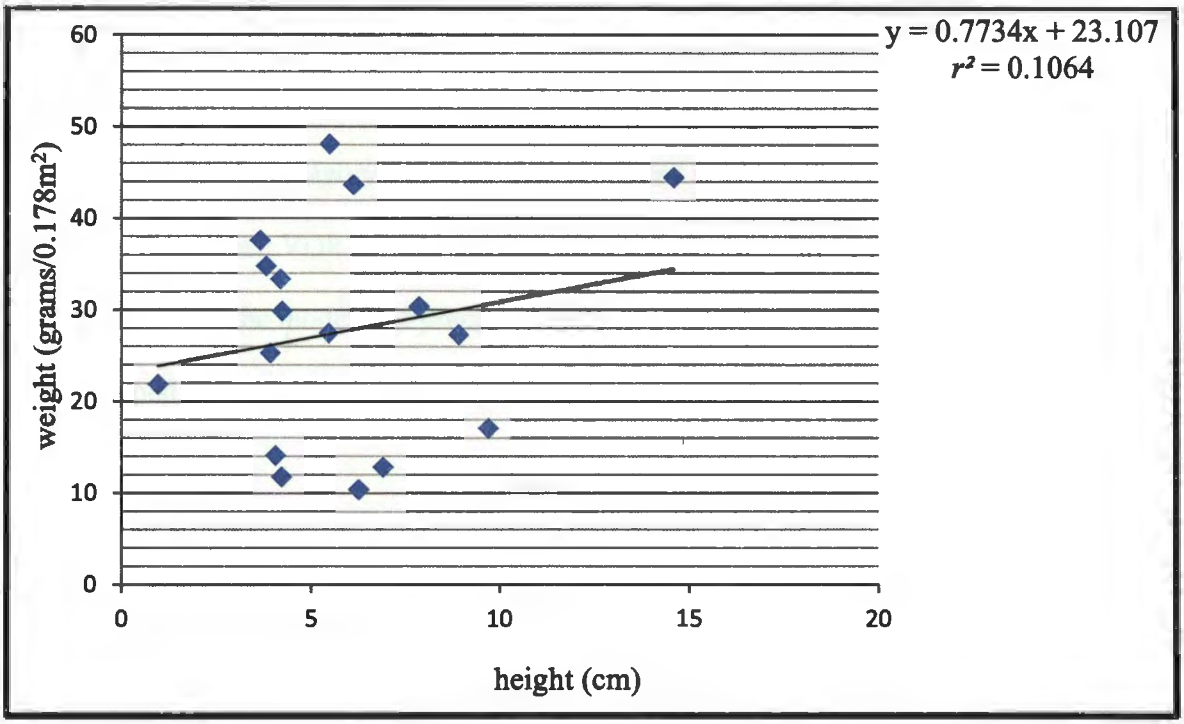

Figure 16. Linear regression model for the sandy ecological site using the block (mean for all individual plots within each block) collected on the Little Missouri National Grasslands – Medora Ranger District in 2008 and 2009.

Herbage Production, Visual Obstruction Readings and Degree of Disappearance

Grand River National Grasslands

Mean herbage production was similar for the clayey, loamy and sandy ecological when comparing the none to light use category (1) in 2008. Average herbage production was 1,543 kg/ha on the clayey (Table 4) and sandy (Table 5) ecological sites. However, the corresponding VOR was 23.6 % lower on the sandy site (6.48 cm) compared to clayey site (8.48 cm). The loamy ecological site was the highest weight and structure producing ecological site of the three studied at 1,669 kg/ha and 8.89 cm on the none to light use category (Table 6).

The model for the clayey ecological site for the GRNG (Figure 9; y = 1.2722x + 24.672) did an excellent job of predicting herbage production from the VOR structure in the none to light use category based on the calculated averages from the clipped data (Table 4). The mean VOR of 8.48 cm determined from the none to light use category was incorporated into the model and predicted herbage production at 1,579 kg/ha, very similar to the clipped (actual) phytomass of 1,543 kg/ha.

Table 4. Average annual herbage production and mean Visual Obstruction Reading (VOR) for clayey ecological sites by degree of disappearance category on the Grand River National Grasslands in 2007 through 2009.

Degree of Disappearance Category[1]	Number of Plots	Average Kg/Ha	SE	Mean VOR (cm)	SE
1	257	1543	839.7	8.48	5.89
2	72	1315	599.9	8.38	7.18
3	64	1242	757.0	6.53	5.26
4	8	685	325.8	3.25	1.04
5	0	0	0.0	0.00	0.00

[1] 1 represents 0 to 20 % none to light use disappearance, 2 represents 20 to 40 % moderate use disappearance, 3 represents 40 to 60 % full use disappearance, 4 represents 60 to 80 % close use disappearance, and 5 represents 80 to 100 % severe use disappearance.

The model for the sandy ecological site GRNG (Figure 10; y = 2.8934x + 16.296) was also very accurate in predicting herbage production from the VOR structure in the none to light use category based on the calculated averages from the clipped data (Table 5). The mean VOR of 6.48 cm determined from the none to light use category was incorporated into the model and predicted herbage production at 1,560 kg/ha, very similar to the clipped (actual) phytomass of 1,543 kg/ha.

Table 5. Average annual herbage production and mean Visual Obstruction Reading (VOR) for sandy ecological sites by degree of disappearance category on the Grand River National Grasslands in 2007 through 2009.

Degree of Disappearance Category[1]	Number of Plots	Average Kg/Ha	SE	Mean VOR (cm)	SE
1	201	1543	855.9	6.48	4.13
2	57	1334	589.4	5.28	3.04
3	0	0	0.0	0.00	0.00
4	0	0	0.0	0.00	0.00
5	0	0	0.0	0.00	0.00

[1]1 represents 0 to 20 % none to light use disappearance, 2 represents 20 to 40 % moderate use disappearance, 3 represents 40 to 60 % full use disappearance, 4 represents 60 to 80 % close use disappearance, and 5 represents 80 to 100 % severe use disappearance.

The model for the loamy ecological site GRNG (Figure 8; $y = 1.6828x + 22.686$) was good at predicting herbage production from the VOR structure in the none to light use category based on the calculated averages from the clipped data (Table 6). The mean VOR of 8.89 cm determined from the none to light use category was incorporated into the model and predicted herbage production at 1,678 kg/ha, very similar to the clipped (actual) phytomass of 1,669 kg/ha.

Table 6. Average annual herbage production and mean Visual Obstruction Reading (VOR) for loamy ecological sites by degree of disappearance category on the Grand River National Grasslands in 2007 through 2009.

Degree of Disappearance Category[1]	Number of Plots	Average Kg/Ha	SE	Mean VOR (cm)	SE
1	519	1669	813.8	8.89	6.38
2	168	1494	1687.2	7.01	6.71
3	71	1033	584.5	5.28	4.88
4	16	680	418.5	3.18	1.31
5	0	0	0.0	0.00	0.00

[1]1 represents 0 to 20 % none to light use disappearance, 2 represents 20 to 40 % moderate use disappearance, 3 represents 40 to 60 % full use disappearance, 4 represents 60 to 80 % close use disappearance, and 5 represents 80 to 100 % severe use disappearance.

Little Missouri National Grasslands - McKenzie Ranger District

Mean herbage production was similar for the clayey, loamy and sandy ecological sites when comparing the none to light use category (1) on the McRD in 2008 and 2009. Average herbage production was 1,696 kg/ha on the clayey (Table 7), 1,600 kg/ha on the loamy (Table 8) and 1,574 kg/ha on the sandy (Table 9) ecological site for the none to light use category.

The model for the clayey ecological site (Figure 12; $y = .4959x + 26.678$) under-estimated herbage production compared to the calculated averages from the clipped data when using the mean VOR structure value in the none to light use category from the clipped data (Table 7). The mean VOR of 3.86 cm from the none to light use category was incorporated into the model and predicted herbage production at 1,273 kg/ha compared to the clipped (actual) phytomass of 1693 kg/ha.

Table 7. Average annual herbage production and mean Visual Obstruction Reading (VOR) for clayey ecological sites by degree of disappearance category on the Little Missouri National Grasslands - McKenzie Ranger District in 2008 and 2009.

Degree of Disappearance Category[1]	Number of Plots	Average Kg/Ha	SE	Mean VOR (cm)	SE
1	126	1693	888.2	3.86	3.81
2	0	0	0.0	0.00	0.00
3	6	1041	492.7	3.38	3.02
4	0	0	0.0	0.00	0.00
5	0	0	0.0	0.00	0.00

[1] 1 represents 0 to 20 % none to light use disappearance, 2 represents 20 to 40 % moderate use disappearance, 3 represents 40 to 60 % full use disappearance, 4 represents 60 to 80 % close use disappearance, and 5 represents 80 to 100 % severe use disappearance.

These findings were similar for the loamy and sandy ecological sites on the McRD with the model under-estimating herbage production. The model for the loamy ecological site (Figure 11; y = .5772x + 20.079) using the mean VOR of 3.26 cm (Table 8) determined from the none to light use category was incorporated into the model and predicted herbage production at 978 kg/ha compared to the clipped (actual) phytomass of 1,600 kg/ha. The model for the sandy ecological site (Figure 13; y = .7734x + 23.107) using the mean VOR of 4.47 cm (Table 9) determined from the none to light use category was incorporated into the model and predicted herbage production at 1,183 kg/ha compared to the clipped (actual) phytomass of 1,574 kg/ha.

Table 8. Average annual herbage production and mean Visual Obstruction Reading (VOR) for loamy ecological sites by degree of disappearance category at the Little Missouri National Grasslands - McKenzie Ranger District in 2008 and 2009.

Degree of Disappearance Category[1]	Number of Plots	Average Kg/Ha	SE	Mean VOR (cm)	SE
1	126	1600	1100.1	3.26	2.70
2	24	1359	680.1	2.30	1.59
3	6	931	404.1	1.06	0.52
4	0	0	0.0	0.00	0.00
5	0	0	0.0	0.00	0.00

[1] 1 represents 0 to 20 % none to light use disappearance, 2 represents 20 to 40 % moderate use disappearance, 3 represents 40 to 60 % full use disappearance, 4 represents 60 to 80 % close use disappearance, and 5 represents 80 to 100 % severe use disappearance.

Table 9. Average annual herbage production and mean Visual Obstruction Reading (VOR) for sandy ecological sites by degree of disappearance category on the Little Missouri National Grasslands - McKenzie Ranger District in 2008 and 2009.

Degree of Disappearance Category[1]	Number of Plots	Average Kg/Ha	SE	Mean VOR (cm)	SE
1	24	1574	666.3	4.47	2.20
2	0	0	0.0	0.00	0.00
3	0	0	0.0	0.00	0.00
4	0	0	0.0	0.00	0.00
5	0	0	0.0	0.00	0.00

[1] 1 represents 0 to 20 % none to light use disappearance, 2 represents 20 to 40 % moderate use disappearance, 3 represents 40 to 60 % full use disappearance, 4 represents 60 to 80 % close use disappearance, and 5 represents 80 to 100 % severe use disappearance.

Little Missouri National Grasslands - Medora Ranger District

Mean herbage production was lowest on the clayey, and similar between the loamy and sandy ecological sites when comparing the none to light use category (1) in 2008 and 2009. Average herbage production was 711 kg/ha on the clayey ecological sites with a mean VOR of 4.91 cm (Table 10). The loamy (Table 11) and sandy (Table 12) ecological sites on the none to light use category had similar production at 978 kg/ha and 990 kg/ha; respectively, and mean VOR of 5.86 and 4.61 cm, respectively.

The model for the clayey ecological site (Figure 15; y = .5347x + 14.244) did a good job of predicting herbage production from the mean VOR value of the clipped data in the none to light use category. When the mean VOR of 4.91 cm was incorporated into the model, it predicted herbage production at 751 kg/ha and similar to the clipped (actual) phytomass of 711 kg/ha (Table 10).

Table 10. Average annual herbage production and mean Visual Obstruction Reading (VOR) for clayey ecological sites by degree of disappearance category on the Little Missouri National Grasslands - Medora Ranger District in 2008 and 2009.

Degree of Disappearance Category[1]	Number of Plots	Average Kg/Ha	SE	Mean VOR (cm)	SE
1	44	711	394.9	4.91	7.33
2	12	1064	483.0	6.30	6.22
3	0	0	0.0	0.00	0.00
4	0	0	0.0	0.00	0.00
5	0	0	0.0	0.00	0.00

[1]1 represents 0 to 20 % none to light use disappearance, 2 represents 20 to 40 % moderate use disappearance, 3 represents 40 to 60 % full use disappearance, 4 represents 60 to 80 % close use disappearance, and 5 represents 80 to 100 % severe use disappearance.

The model for the loamy ecological site (Figure 14; y = .9249x + 13.857) under-estimated the predicted herbage production value from the mean VOR data in the none to light use category. Using the mean VOR of 5.86 cm from the none to light use category, the predicted herbage production was 858 kg/ha compared to the clipped (actual) phytomass of 978 kg/ha (Table 11).

Table 11. Average annual herbage production and mean Visual Obstruction Reading (VOR) for loamy ecological sites by degree of disappearance category on the Little Missouri National Grasslands - Medora Ranger District in 2008 and 2009.

Degree of Disappearance Category[1]	Number of Plots	Average Kg/Ha	SE	Mean VOR (cm)	SE
1	118	978	577.4	5.86	4.18
2	20	1314	666.8	8.83	5.61
3	0	0	0.0	0.00	0.00
4	0	0	0.0	0.00	0.00
5	0	0	0.0	0.00	0.00

[1] 1 represents 0 to 20 % none to light use disappearance, 2 represents 20 to 40 % moderate use disappearance, 3 represents 40 to 60 % full use disappearance, 4 represents 60 to 80 % close use disappearance, and 5 represents 80 to 100 % severe use disappearance.

The model for the sandy ecological site (Figure 16; y = .7734x + 23.107) was the only model among the study areas and ecological sites to over-estimate the predicted herbage production from the mean VOR data in the none to light use category. Using the mean VOR of 4.61 cm from the none to light use category in the model, it predicted the herbage production at 1187 kg/ha compared to the clipped (actual) phytomass of 990 kg/ha (Table 12).

Table 12. Average annual herbage production and mean Visual Obstruction Reading (VOR) for sandy ecological sites by degree of disappearance category on the Little Missouri National Grasslands - Medora Ranger District in 2008 and 2009.

Degree of Disappearance Category[1]	Number of Plots	Average Kg/Ha	SE	Mean VOR (cm)	SE
1	27	990	1056.8	4.61	4.33
2	26	10320	357.0	3.96	3.24
3	0	0	0.0	0.00	0.00
4	0	0	0.0	0.00	0.00
5	0	0	0.0	0.00	0.00

[1]1 represents 0 to 20 % none to light use disappearance, 2 represents 20 to 40 % moderate use disappearance, 3 represents 40 to 60 % full use disappearance, 4 represents 60 to 80 % close use disappearance, and 5 represents 80 to 100 % severe use disappearance.

DISCUSSION

The height:weight correlations on the clayey, loamy and sandy ecological sites were evaluated for predictability of phytomass potential using the VOR. The r^2 using a linear regression model was similar for each ecological site when all sites (grassland locations) were combined; however, there was variation among the three study areas. Vader (2000) evaluated the correlation between height and weight on different ecological sites and had better regressions on ecological sites with more species evenness and homogeneity (i.e. loamy ecological site). Vader (2000) found sites that had the best fit were sites higher in Kentucky bluegrass presence and of mid topographic location.

A study conducted by Vermeire and Gillen (2001) found VOR was less effective at measuring standing crop when individual plots were used as observations. Separate models were required for estimating the standing crop on individual plots located on different grazing intensities. We studied the use of individual plots and blocks for estimating herbage production using the VOR and found neither method effective, similar to Vermeire and Gillen (2001) using individual plots. The dramatic difference between Vermeire and Gillen (2001) and our study could be best explained in the methodology. The VOR for each individual plot in Vermeire and Gillen (2001) study was derived from one reading taken from the farthest, outer edge of the frame. Our VOR measurement was the average of the four cardinal directions taken from the center of the frame, similar to Robel et al. (1970). Our methodology would increase the risk of an individual plant giving a high VOR in less productive sites. Vermeire and Gillen (2001) also predicted total standing crop from standing crop; whereas, we predicted phytomass from VOR standing crop. Litter content can be quite variable in standing crop, leaving greater room for error in predicting phytomass.

The studies conducted by Benkobi et al. (2000) and Uresk et al. (2007) focused on vegetative type across ecological sites, using the community as the experimental unit for determining if a height:weight correlation exists between VOR and standing crop. Unlike our findings, both Benkobi et al. (2000) and Uresk et al. (2007) found a high correlation between VOR and standing crop. This study was similar to our research area and protocol for testing a height:weight correlations; however, we further stratified by ecological site, reducing the natural variability from low production (low structure) to high production (high structure) found across a landscape. Stratifying by ecological site allows for a comparison between these sites on the three different study areas. This monitoring at the ecological site level is critical, as carrying capacity of rangelands is determined by developing an ecological site map for each pasture with herbage production or phytomass determined for each ecological site (USDA, NRCS 2003). Knowing the actual production, or predicting production, of each ecological site within a landscape is required for land managers to better understand livestock use through grazing distribution, plant use, and impacts to wildlife habitat. The three ecological sites studied in our trial appear to be very diverse, both in plant species and structure, creating fair to poor correlations between VOR and phytomass, depending on study location.

The predicted herbage production using the mean VOR value from the field sample sites of the none to light degree of disappearance category was similar to the clipped herbage production from this category for blocks clipped during peak herbage production (late June – mid August) when the r^2 was approximately 0.4 or greater. However, when the adjusted r^2 was poor (0.27 or less), the predicted herbage production using the mean VOR from the none to light degree of disappearance category was quite different than the clipping (actual) production. In all cases but the sandy ecological site on the Medora Ranger District, the predicted phytomass (herbage production) was lower than the phytomass from the clipped (actual) sites.

SUMMARY AND CONCLUSION

Visual obstruction readings are used to determine the structure of vegetation, particularly as it relates to nesting bird habitat. The objective of this study was to evaluate if VOR used to determine amount of vegetative cover for wildlife can be used for determining yearly phytomass or herbage production for livestock use. Although a significant correlation existed between the VOR height and phytomass in the mixed grass prairie of western North Dakota within the Little Missouri Grassland and northwestern South Dakota within the GRNG, the correlations or regressions were poor. The best regression was on the loamy ecological site and least fit regression on the clayey site.

The best fit regression from the individual ranger districts was for the GRNG. The best regression model was on the sandy ecological site and lowest regression model was on the clayey site. The regression model was similar for the clayey and sandy ecological sites, with very poor correlations for both the McRD and MRD. The loamy ecological site had the best regression fit between the two McRD and MRD.

The correlation between height:weight was best predicted at GRNG based on the actual clipping data from the grazing intensity treatments. The regression models at GRNG had phytomass similar to the predicted value, with the clayey 2%, loamy 1%, and sandy ecological sites 0.5% over-estimated. However, the poor regression values for the height:weight model at Medora and McKenzie tended to under-estimate herbage production or phytomass by 20-40%. Herbage production on the clayey site at the McRD was under-estimated by 25%, loamy sites 38%, and sandy sites 25%.

The MRD had the greatest variability or inconsistency when comparing predicted herbage production and actual clipped production. The predicted herbage production from the model for the clayey sites was similar to the clipped (actual) production at less than 5% different. However, the model under-predicted herbage production on the loamy site by 12% and over-estimated on the sandy site by 20%.

The height:weight model for predicting herbage production or phytomass from VOR was similar to the clipping (actual) production during the peak season when the regression model r^2 was greater than 0.4. However, when the regression model r^2 is less than 0.4, the model tends to under-estimate phytomass by 12 to 38%.

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APPENDIX A

Blocks were stratified by ecological site. Blocks are defined as the mean for all individual plots within each pasture unit. Plots are the average reading for a site within a block.	
All clayey plots	401
All loamy plots	774
All sandy plots	258