Calculating Accurate Aboveground Dry Weight Biomass of Herbaceous Vegetation in the Great Plains: A Comparison of Three Calculations to Determine the Least Resource Intensive and Most Accurate Method

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Abstract—*Obtaining accurate biomass measurements is often a resource-intensive task. Data collection crews often spend large amounts of time in the field clipping, drying, and weighing grasses to calculate the biomass of a given vegetation type. Such a problem is currently occurring in the Great Plains region of the Bureau of Indian Affairs. A study looked at six reservations in the Great Plains region to compare three methods of calculating aboveground dry weight biomass to determine the least resource-intensive method. Data were collected in the six agencies using a modified FIREMON plot layout that included plot description (PD), fuel loading (FL), and cover frequency (CF). Additionally, grasses were clipped and weighed on ten 20 inch X20 inch frames per plot. Analyses were performed on the plot data to calculate the dry weight biomass of each plot using three common methods. The first method, considered to be the most accurate, calculated biomass using the ECODATA clip-and-weigh (CW) protocol where the dry weight of the vegetation is converted to pounds/acre based on the frame size of 20 inches X 20 inches. The second method used the FIREMON bulk density constant of 0.8 kg/m^{3,} which is multiplied by average height and percent cover of the vegetation and was applied to the FL and CF data. Last, a regional bulk density constant was established using the CW data. The study then compares the accuracy of both the FIREMON bulk density constant and the regional constant to the CW method. The results of this study provide a regional bulk density constant that can be used to generate accurate biomass calculations, which eliminates the need for the resource-intensive CW method.*

Introduction

Proper management of grasses through the use of fire and other methods promotes healthy grassland that is free from nonnative, invasive shrub and tree species encroachment. Accurate estimations of aboveground dry weight biomass are crucial to the management of native grassland and prairie ecosystems. Fire, as a management tool, relies on fuel readily available for consumption. When the biomass of herbaceous vegetation reaches a desirable level, managers are able to effectively use prescribed fire as a tool to promote new growth of native grasses and forbs. An increase in biomass often leads to increased litter production by herbaceous vegetation which in turn causes a decrease in forgeable grass production rates; therefore, timing is critical when burning grasslands.

Gathering biomass data is important for predicting the most effective time to use prescribed fire as a tool and to help explain postfire effects for a given fuel treatment. However, the gathering of this data is often time- and

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resource-intensive, leading to a decrease in accurate measurements for a given management area. The clip-and-weigh (CW) method is the most time consuming; however, it yields the most accurate biomass value. The FIREMON cover frequency (CF) and fuel load (FL) methods allow data collection crews to make estimations of cover and height to be recorded for calculations. These estimations allow the crew to function at a much faster pace, which in turn results in less consumption of time and resources. A field comparison by the data collection crew used to gather the data for this study shows that the CW method uses 100 percent more time to derive a biomass value when compared to the FIREMON CF and FL methods.

The overall goal of this study is to generate a regional bulk density constant that can be used to calculate accurate aboveground dry weight biomass values. The regional constant was created in an effort to rely more heavily on the CF and FL methods outlined in the FIREMON methods (Lutes and others 2006) as the field protocol for generating biomass values within the Great Plains region of the Bureau of Indian Affairs (BIA).

Study Sites

Study sites were in the Great Plains region of the BIA in North Dakota, South Dakota, and Nebraska (fig. 1). Six reservations were sampled throughout summer 2006 by placing plots within nine preestablished burn units (table 1). Plot locations were determined randomly using a standard GIS protocol to ensure minimal bias. All plots were placed in burn units that consisted of the mixed grass prairie vegetation type.

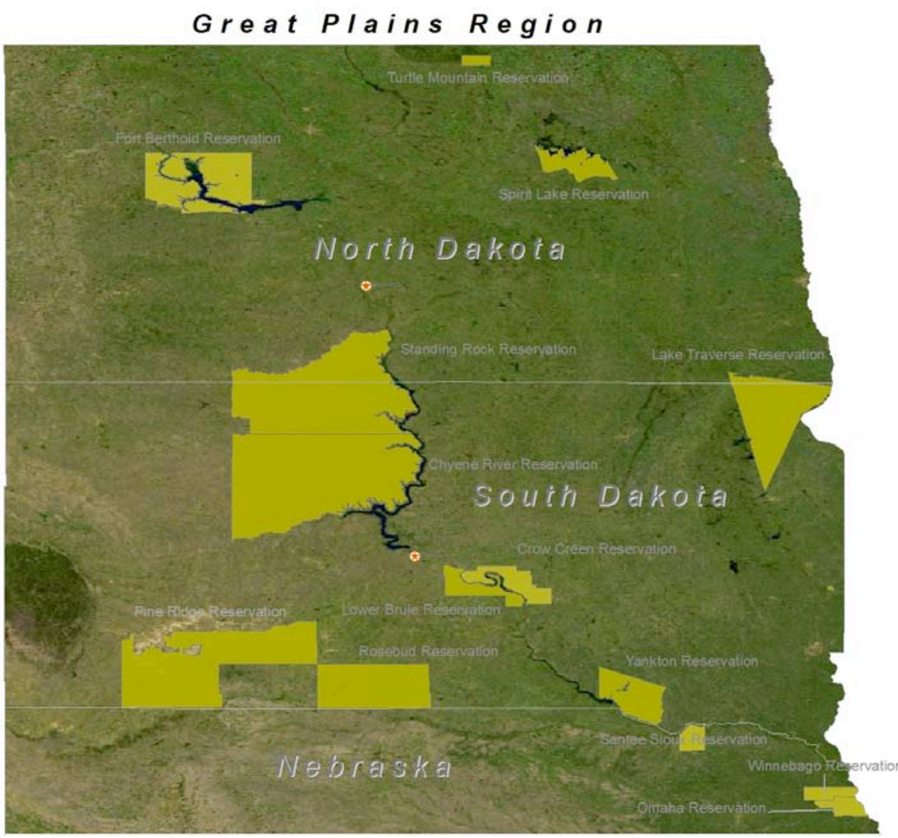

Figure 1—Map showing the Great Plains Region of the BIA and the reservations sampled.

Table 1—Summary of plots sampled by reservation and corresponding burn unit.

Reservation	Burn unit	Number of plots	CF quadrats	FL veg. cylinders	CW quadrats
Crow Creek	Carpenter	8	200	32	80
Fort Berthold	North School	8	200	32	80
	Wild Boar Ridge	6	150	24	60
Omaha	600/599	8	200	32	80
	Altmt. 125	5	125	20	50
	S. Harlan	3	75	12	30
Winnebago	148-149	4	100	16	40
Ponca	East Pen	13	325	52	130
Santee	ST Bar	17	425	68	170
Totals		**72**	**1800**	**288**	**720**

Field Measurements

Field sampling was performed by a team of four Student Conservation Association (SCA) interns and one SCA field staff member. The team was assisted by one or more Tribal staff members who provided local expertise. All team members were trained in standard FIREMON and ECODATA methods to ensure consistency in data collection techniques.

The plot design employed the FIREMON cover frequency (CF) and fuel load (FL) methodologies (Lutes and others 2006) and the ECODATA clip-and-weigh (CW) methodologies (Jensen and others 1993). CF and CW data were collected using a baseline running in an upslope direction from plot center and transects running perpendicular to that baseline across the slope (fig. 2). There were five transects running from the baseline upon which quadrats were located to sample vegetation data. Each transect contained five CF quadrats located on the upslope side of the line. Data were then collected in each frame and included cover estimates and the average height of each species rooted in the frame.

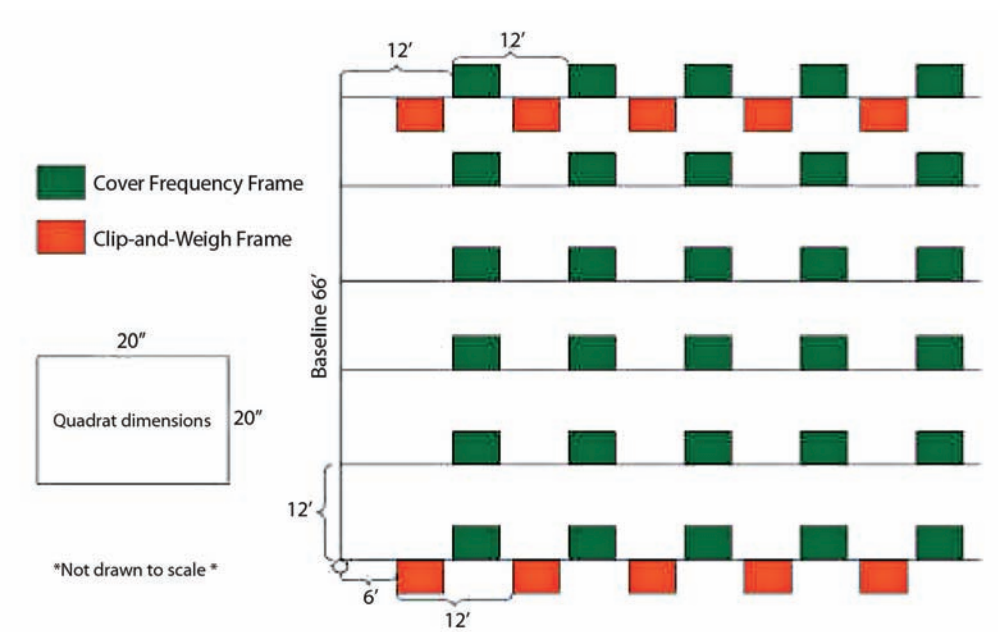

Figure 2—Plot design showing location and number of clip-and-weight quadrats and cover frequency quadrats.

Five CW quadrats were placed on the down slope side of the first and fifth transect. Herbaceous vegetation was clipped in each frame, and the average height of the vegetation was recorded. Tree and shrub species were not clipped to ensure the sample was comparable to the CF and FL methods.

The FL data were collected along transect lines running from plot center. Each transect followed one of the cardinal compass directions and contained two sampling cylinders. The sampling cylinders measured 6 inches in diameter and height and were located at the 45 foot and 75 foot mark on the transects (fig. 3). The average height of dead and live herbaceous vegetation, and the total cover were recorded for each cylinder using FIREMON cover classes (Lutes and others 2006).

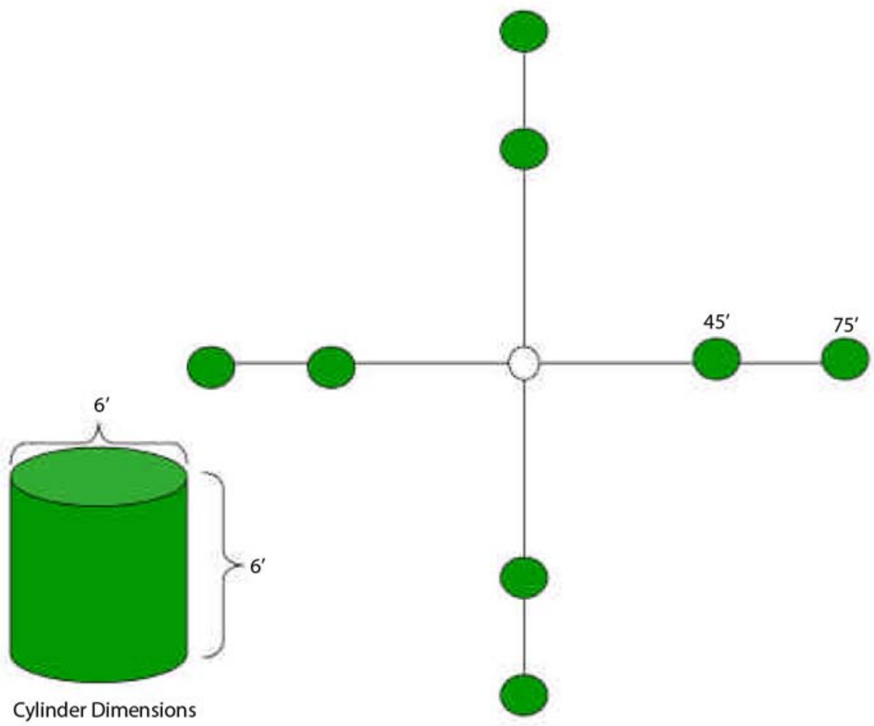

Figure 3—Plot design showing location and number of fuel load vegetation cylinders.

Data Analysis and Exploration

Weights were recorded for each CW quadrat sampled throughout the study area. Each sample was dried for 1 week or until the sample weight stabilized and then weighed to the nearest 0.1 gram. The dry gram weights were converted to pounds by multiplying by 0.0022 resulting in a pounds/20 inch x20 inch frame. Next, the values were multiplied by a 15681.6 conversion factor to generate a resulting tons/acre value for each quadrat. The individual quadrat biomass values were then averaged for each plot to generate a biomass value recorded in tons/acre.

FL vegetation cylinders were used to calculate the biomass values of herbaceous vegetation per plot. The FIREMON v. 2.1.2 software was used to perform this calculation (Lutes and others 2006). The software generated a biomass value for both the live and dead herbaceous component and these values were summed to generate a total biomass value for each plot. Again, the individual quadrat biomass values were averaged, resulting in an average biomass value for the study area recorded in tons/acre.

For the CF frames a biomass value was calculated for each herbaceous species inventoried by using the FIREMON bulk density equation B=H*C*BD (where H = average height, C = average cover, BD = bulk density (.8 kg m^3), and B = biomass) (Lutes and others 2006). The biomass values of each individual species rooted in the quadrat were then summed resulting in a kg/m^2 biomass value for the plot. The values were then multiplied by a 4.46 conversion factor to generate a resulting tons/acre biomass value for each plot. The plot values were then averaged to generate a biomass value for the study area.

The FIREMON biomass equation (B=H*C*BD) was also used to generate a regional bulk density constant. The CF data were used to calculate the values for the equation. The cover estimates for each plot were summed and the plot totals were averaged resulting in 12 percent as the average cover estimate for the study area. The height estimations from the CF data were averaged resulting in 0.48m as the average height of vegetation in the study area. Finally the average biomass of 0.397 kg/m^2 was determined from the CW data. The results produced a regional bulk density constant of 6.89 kg/m^3.

The regional bulk density constant was then used in the FIREMON biomass equation (B = H*C*BD) and calculations were performed on the CF and FL (resulting biomass values noted as CF-R, FL-R). Biomass values for the CF plots were calculated for each species rooted in a plot quadrat. The individual biomass values were then summed resulting in a biomass value for each plot. Calculations were also performed on the FL data set using the regional bulk density constant. Two biomass values were calculated for each plot (live herbaceous and dead herbaceous) using the FIREMON bulk biomass equation. The two biomass values were then summed to calculate the total biomass of each plot.

Results and Discussion

The relationship between CW, CF, and FL biomass values was consistently poor for each burn unit in the study area. The CW method produced an average of 1.773 tons/acre for the entire study area with the CF and FL methods averaging 0.325 and 0.308 tons/acre respectively (fig. 4). There was noted to be an average difference of 1.448 tons/acre difference between the CW and CF method and a 1.462 tons/acre difference between the CW and FL methods. The FIREMON bulk density constant of 0.8 kg/m^3 therefore proved to be an inaccurate constant when compared to the CW data set.

A comparison of the biomass values calculated using the regional bulk density constant was also performed. The average biomass values were calculated for the CF-R and FL-R datasets and were noted to be 2.655 tons/acre and 1.50 tons/acre, respectively (fig. 5). When compared to the biomass value of 1.773 recorded from the CW method the relationship proved to be much improved.

It was determined that further investigation of the poor performance of the FIREMON method's data set was needed to confirm the CW values. The three average biomass values (CF, FL, CW) were compared to the Natural Fuels Photo Series (Ottmar and Vihnanek 1999). Volume V was used as a compari-

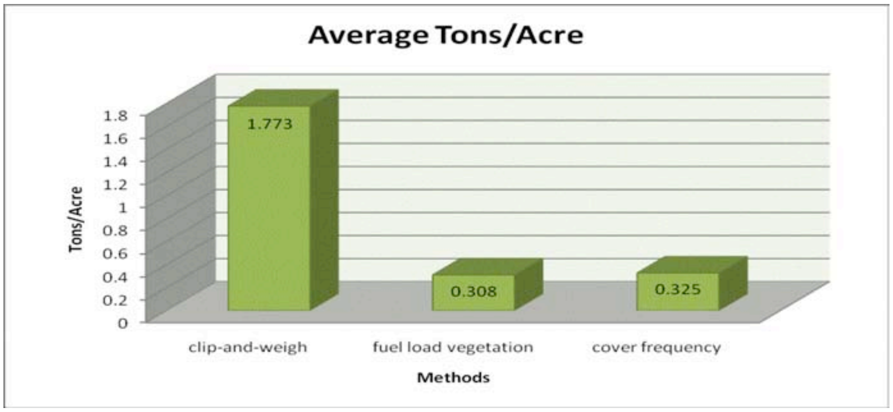

Figure 4—Comparison of the CW method to the FL and CF.

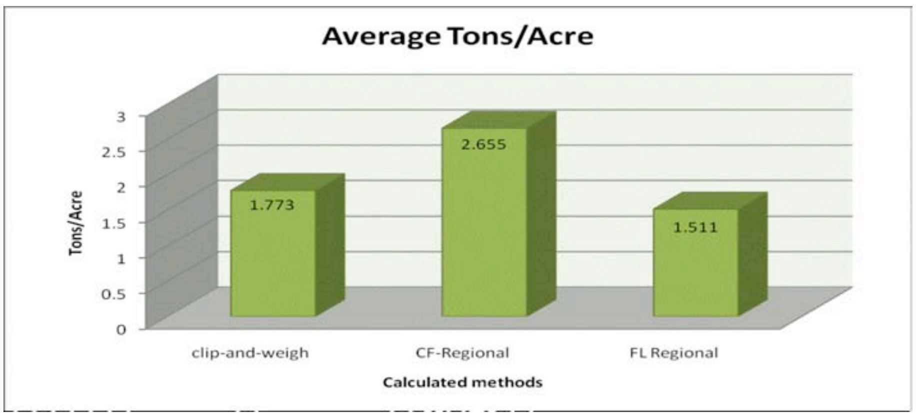

Figure 5—Comparison of the CW method to the CF-R and FL-R.

son to validate the CW biomass value. The northern tall grass prairie photo series was used and the area was determined to be most closely related to the TP 5 photo. The photo series provides a total biomass value of 1.718 tons/acre when subtracting the surface fuel and shrub components. This value compared well with the average CW biomass of 1.773 for the reservation, however, when compared to the CF and FL biomass values of 0.325 and 0.308 respectively, the relationship proved once again to be poor.

Cover estimates were examined as a possibility of the seemingly low biomass values yielded through the CF and FL methods. An average of 12 percent herbaceous vegetation cover was recorded by the field crew for the study area. Examination of photo documentation from the field crew solidified their cover estimates for each quadrat (fig. 6). Crew precision did not prove to be a factor in the FIREMON biomass calculations.

The bulk density constant used in the FIREMON calculations (0.8 kg/m^3) was questioned as a potential influence in the low biomass values. This constant was compared to Brown's *Bulk Densities of Nonuniform Surface Fuels and Their Application to Fire Modeling* (Brown 1981), which lists a bulk density constant of 0.8 kg/m^3 for upright surface strata located in the grass-shrub vegetation type. Being that the constant used in the FIREMON calculations was the same, the constant was considered to be accurate. Both constants, however, rely on forest vegetation types and do not necessarily represent the mixed grass prairie ecosystem.

Figure 6—Documentation showing quadrat before clipping (left) and after clipping (right).

The excellent relationship between the FL-R value and the CW value proves to be one of significance and it was therefore determined to be the most accurate, least time consuming method of producing biomass values.

Summary and Conclusions

The data clearly show a poor performance of the 0.8kg/m^3 bulk density constant when applied to the FIREMON CF and FL. Exploration into possible causes of this poor performance leads to the fact that national bulk density constants make poor predictors of actual biomass values when reduced to a smaller scale. This is noted in the loose relationship between the CW, CF, and FL methods when applying the national bulk density constant. The creation of local constants is essential to calculating accurate biomass values for a given ecosystem.

Accuracy of data collection crews also proves important when determining biomass in grasslands. The creation of a regional constant cannot be completed without accurate cover and height estimates, and therefore crew calibration is necessary in the early stages of sampling design.

The regional bulk density constant of 6.89 kg/m^3 proves to be a sound value and displayed a consistent relationship with the CW data when applied to the FL data set. Further analysis will be performed on the data set to examine the loose relationship between the CF and CW methods when applying the regional bulk density constant. Additional comparisons will also be performed in the future with the project set to be reexamined throughout summer 2007, with the overall goal still being to provide the most accurate bulk density constant possible for use by fire professionals throughout the Great Plains region of the BIA.

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