ESTIMATING STANDING VEGETATION WITH A MODIFIED ROBEL POLE ON MEADOWS AND GRASSLANDS IN THE SOUTHERN BLACK HILLS OF SOUTH DAKOTA

Daniel W. Uresk[1], Daryl E. Mergen[2], and Ted A. Benzon[3]
[1] USDA Forest Service
231 East Saint Joseph Street
Rapid City, SD. 57701.
[2] Colorado State University
1835 Parkview Boulevard
Colorado Springs, CO 80905
[3] South Dakota Department of Game, Fish and Parks
3305 West South Street
Rapid City, SD 57702

ABSTRACT

A modified Robel pole and vegetation clipping were used to collect visual obstruction readings (VOR) data in the southern Black Hills, South Dakota. The objectives were to describe the mathematical relationship between VOR and standing vegetation; the resulting model was used to develop guidelines for monitoring vegetation and to estimate sample size. A linear relationship between VOR and standing vegetation was found with two segments in a piecewise model. Regression coefficients were highly significant ($P \leq 0.001$). Standard error of the biomass mean estimate was 334 kg·ha^{-1} and vegetation ranged from 110 to 2490 kg·ha^{-1} with a mean of 1116 kg·ha^{-1}. Visually obstructed bands had a mean of 3.9 and ranged from 0.1 to 14.5. Cluster analyses identified a tall VOR category with an average standing vegetation potential of 1814 kg·ha^{-1}. A minimum of 4 transects (20 stations per transect) is recommended for monitoring areas 259 hectares (one section) or less to be within 20% of the mean at 80% confidence to estimate standing vegetation. The protocol developed to estimate standing vegetation is precise and easy to apply. This method provides needed information so that managers can develop guidelines based on bands, standing vegetation, or both to monitor livestock and wildlife use.

Keywords

Vegetation, visual obstruction reading (VOR), height-density, livestock, wildlife

INTRODUCTION

The southern Black Hills of South Dakota, is dominated by ponderosa pine (*Pinus ponderosa*) and interspersed with various types of open grassland meadows (Pase and Thilenius 1968, Severson and Boldt 1977, Hoffman and Alexander

1987). Within the Black Hills, management of public lands is changing to meet increased recreation use and esthetic values while maintaining livestock use and wildlife needs. As a result, a practical monitoring technique that is simple, precise and economical to apply in the field is required. Uresk and Benzon (2007) reported on the simplicity of using the calibrated Robel pole in the central Black Hills to estimate standing vegetation in meadows. Uresk and Juntti (2008) reported on the precision and ease of using the calibrated Robel pole to monitor meadows on the northern Big Horn Mountains in Wyoming. A practical monitoring technique that describes vegetation production on meadows is needed to better manage livestock and wildlife use on the southern Black Hills.

The Robel pole is known to be a simple, fast, precise, and economical tool to monitor standing vegetation. Once the relationship between visual obstruction readings (VOR) and standing vegetation has been described, pole use requires small inputs of labor to monitor rangelands and meadows (Robel et al. 1970, Volesky et al. 1999, Benkobi et al. 2000, Vermeire and Gillen 2001, Vermeire et al. 2002, Uresk and Benzon 2007, Uresk and Juntti 2008).

The objectives of this study were to 1) determine the relationship between VORs and standing vegetation, 2) develop guidelines based on 1.27 cm bands (0.5 inches) to monitor standing vegetation, and 3) to estimate sample size for number of transects needed to monitor biomass with selected precision levels.

STUDY AREA

The study area was in the southern Black Hills, South Dakota, United States of America and is characterized as stands of ponderosa pine interspersed with grasslands and grass/forb meadows. Average annual precipitation varies from 43 cm in the foothills (Hot Springs, SD, 113 yr data) to 48 cm at higher elevations (Custer, SD, 96 yr data) (High Plains Regional Climate Center 2008). Most precipitation falls as rain in May and June. Temperatures during the growing season, April through September, range from 7 °C to 22 °C (Orr 1959). The growing season ranges from 97 to 154 days, depending on elevation. Elevation ranges from 1132 m to 1916 m.

Information on plant species composition and diversity are limited in previous studies. Peak standing crop of vegetation in meadows on the study area has been estimated to be 1900 $kg{\cdot}ha^{-1}$ (Coppock et al. 1983). Pase and Thilenius (1968) reported an average of 1806 $kg{\cdot}ha^{-1}$ for bluegrass type meadows. Common plant species in some of these meadows include Kentucky bluegrass (*Poa pratensis*), sedges (*Carex* spp.), western wheatgrass (*Pascopyrun smithii*), prairie dropseed (*Sporobolus heterolepis*), timothy (*Phleum pratense*), smooth brome (*Bromus inermis*) fleabane (*Erigeron* spp.), yarrow (*Achillea millefolium*) and dandelion (*Taraxacum officinale*) (Pase and Thilenius 1968, Coppock et al. 1983). Other grassland types sampled in the study area included common plants species such as little bluestem (*Schizachyrium scoparium*), threadleaf sedge (*Carex filfifolia*), needle-and-thread (*Hesperostipa comata*), blue grama (*Bouteloua gracilis*) and buffalograss (*Bouteloua dactyloides*) (Wydeven and Dahlgren 1985).

METHODS

VORs and clipped vegetation were sampled from early July into September 2005 to include frosted plants. We used a modified Robel pole (Robel et al. 1970 and Uresk and Benzon 2007) with 1.27 cm (0.5 inches) alternating white and grey bands which were numbered beginning with 0 at the bottom. VORs were made from a distance of 4 m with the reader's eyes at a height of 1 m. The lowest visible band obscured by vegetation was recorded (Uresk and Benzon 2007, Uresk and Juntti 2008). At each pole station, 4 VORs were recorded, one for each cardinal direction, and then averaged for each station.

A stratified sampling design that represented three levels of vegetation height—short, mid and tall (based on preliminary inspection)—was used to collect data (Benkobi et al. 2000). A total of 195 transects, 65 in each stratum, was sampled. Individual transects were located randomly within strata. Along the 200 m transect, VOR was recorded at 20 stations spaced 10 m apart. At four stations along each transect (50, 100, 150, and 200 m) standing vegetation was clipped to ground level within a 0.25 m^2 circular hoop centered on the Robel pole. All vegetation was oven-dried at 60 °C for 48 hours, and weighed to the nearest gram. Standing vegetation was expressed as $kg{\cdot}ha^{-1}$.

All VORs and clipped vegetation were averaged for each transect before data analyses. Relationships between VOR and vegetation were analyzed by piecewise regression (Neter et al. 1989, SPSS 2003, SAS 2003). Probability plots were examined for normality of residuals. Significance was ≤ 0.05 unless actual p-values are presented.

Data were analyzed with cluster analyses (ISODATA) for VOR categories (Ball and Hall 1967, del Morel 1975). Data were standardized before analyses by subtracting the mean from each data point and then dividing the result by the standard deviation. Cluster analysis was used to define categories using pole band (cm) and standing vegetation ($kg{\cdot}ha^{-1}$) data as variables. The mean vegetation ($kg{\cdot}ha^{-1}$) of the tall category was used to determine the potential amount of standing vegetation at or near peak growth and to establish management objectives (Benkobi et al. 2000, Uresk and Benzon 2007, Uresk and Juntti 2008). Sample size estimates were estimated for the number of transects required to discriminate among categories at $P \leq 0.20$.

RESULTS

Vegetation ranged from 110 to 2490 $kg{\cdot}ha^{-1}$ with a mean of 1116 $kg{\cdot}ha^{-1}$. VOR bands had a mean of 3.9, and ranged from 0.1 to 14.5 for all transects. The relationship between standing vegetation and VOR was found to be strongly linear within both the lower (0-3.6 bands) and upper (> 3.6 bands) regions of the piecewise regression model (Figure 1). The regression model, intercepts and coefficients were significant ($P \leq 0.01$). Standard error of the estimate for a single transect mean was 334 $kg{\cdot}ha^{-1}$ with an $r^2 = 0.65$. Therefore, standing vegetation can be predicted by applying the mean band readings per transect to one of two equations: 1) if band average ≤ 3.6, then vegetation ($kg{\cdot}ha^{-1}$) = 218 + 306 * Bands and 2) if band average > 3.6, then vegetation (kg·ha^{-1}) = 1080 + 68 * Bands (Figure 1).

Cluster analysis (ISODATA) based on pole bands and standing vegetation resulted in four VOR categories (Figure 1 and Table 1). These VOR categories are short (0.1-2.3 bands), short intermediate (2.4-4.2 bands), tall intermediate (4.3-7.7 bands) and tall (7.8-14.5+). The tall category (n = 21) had an estimated mean potential of standing vegetation of 10.8 bands (1814 kg·ha^{-1}) in the study area.

A minimum of four transects with 20 stations and four readings per station is required to detect differences between and among the VOR categories at 80% confidence to be within 20% of the mean standing biomass in kg·ha^{-1} in the southern Black Hills (Benkobi et al. 2000). To detect differences between bands; e.g., for band 2 vs band 3, we used a one-sided t-test (Steel and Torrie 1980) and estimated that four transects will provide sufficient precision at the 95% confidence. Four transects is similar to what Uresk and Juntti (2008) reported in the Big Horn Mountains, Wyoming.

DISCUSSION

The linear relationship between VOR and standing vegetation for meadow vegetation and grasslands in the southern Black Hills of South Dakota was significant ($r^2 = 0.65$, $P \leq 0.001$). Differences among meadows and grasslands were due to the variability in plant species and range sites sampled within the study area (Wydeven and Dahlgren 1985). Even so, a minimum of four transects per section (640 acres, 256 ha) is adequate for monitoring vegetation (VOR). Although the standard error of prediction was large for small VOR, the standard error remained constant (334 kg·ha^{-1}) throughout the range of vegetation pre-

Table 1. Visual obstruction reading (VOR) categories defined by cluster analysis for short, short intermediate, tall intermediate and tall strata categories. VOR bands (0.5 inch band, 1.27 cm) on a modified Robel pole with corresponding kg·ha^{-1}.

Category	VOR band kg ha^{-1}	minimum	mean	maximum
Short	band	0.1	1.1	2.3
(n = 60)[1]	kg·ha$^{-1, 2}$	249	556	924
Short intermediate	band	2.4	3.5	4.2
(n = 67)	kg·ha^{-1}	955	1293	1366
Tall intermediate	band	4.3	5.0	7.7
(n = 47)	kg·ha^{-1}	1372	1420	1603
Tall	band	7.8	10.8	14.5+
(n = 21)	kg·ha^{-1}	1610	1814	2066

[1] Number of transects based on ISODATA cluster analyses.

[2] kg·ha^{-1} based on VOR band-weight equations.

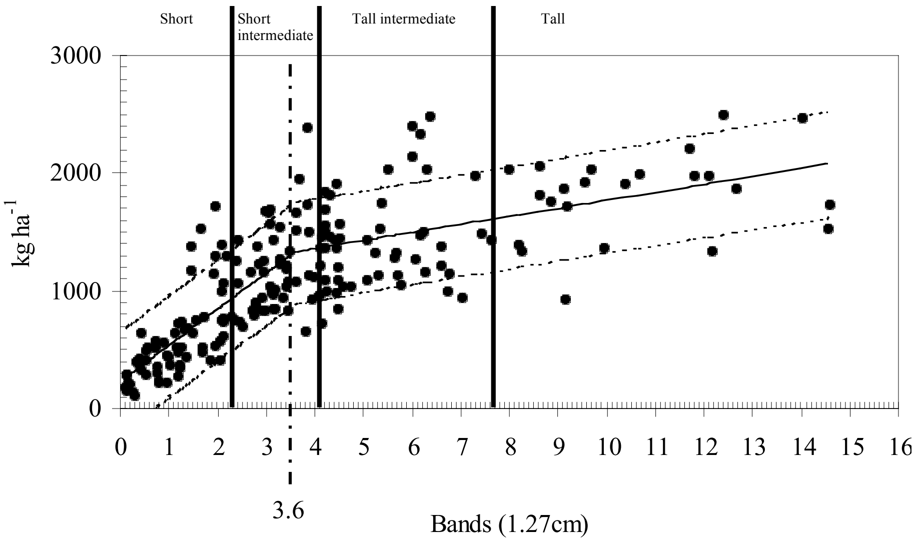

Figure 1. Piecewise regression relationship between pole bands (cm) and standing vegetation (kg ha^{-1}) with 80% prediction limits for individual transect data (r^2 = 0.65, SE = 334 kg ha^{-1}). Piecewise equations provide an estimate of predicting residual standing vegetation. The first segment of the equation predicts vegetation for bands 0 to 3.6 (band average ≤ 3.6; vegetation (kg ha^{-1}) = 218 + 306 * band) and the second segment predicts vegetation for bands greater than 3.6 (band average > 3.6; vegetation (kg ha^{-1}) = 1080 + 68 * band).

diction. Thus, transects located randomly within monitored areas will produce estimates that are sufficiently precise for management needs.

As reported in other studies (Benkobi et al. 2000, Ganguli et al. 2000, Vermeire and Gillen 2001), piecewise linear regression provided the best description of the relationship between VOR and standing crop biomass. In this regression model, the slope changes at a break point yielding a different linear relationship between VOR and standing crop biomass for bands 0 to 3.6 and bands > 3.6.

In the southern Black Hills, the modified Robel pole is an excellent tool to estimate standing crop of vegetation throughout the growing season, even in grazed areas. We based our upper limits for potential vegetation in the southern Black Hills on the mean standing crop of the tall category (1814 kg·ha^{-1}). Coppock et al. (1983) reported 1900 kg·ha^{-1} for the southern Black Hills area which is in agreement with the results of our study. With a management objective of 40% utilization based on the mean production of the tall category, a pasture may be grazed to a level of approximately 3 bands (1.5 inches of total obstruction) or about 1100 kg·ha^{-1} for the study area.

Because approximately 40% use is considered a general standard for light grazing (Heady and Child, 1994, Holecheck et al. 1989), we recommend that a VOR of 3 bands, at a minimum, remain at the end of the livestock grazing period, at which time livestock should be removed from the pasture or area. The length of the grazing season and/or the number of livestock may be increased during wet years, or reduced during dry years. Bement (1969) achieved resource objectives for standing vegetation on the short grass prairie by removing vegetation until a desired residual amount remained at the end of the grazing period to sustain a productive grassland system.

To maintain both plant and animal diversity, we suggest an assortment of the four strata. Approximately 10-15% in each of the short and tall VOR categories is recommended for resource management, thus providing a full range of vegetation for livestock, wildlife (Mueller-Dombois and Ellenberg, 1974), and other resources.

ACKNOWLEDGMENTS

This study was in cooperation with Black Hills National Forest, South Dakota Game Fish and Parks, and Colorado State University, Department of Rangeland Ecosystem Science (28-CR3-752 and 03-JV-1221609-272) with special thanks to Dr. Dennis Child. Thanks are extended to Kurtis Cooper, Scott Thomasson, Tom Berdan, Christina Nelson, and Carin J. Corley for data collection, weighing, maps and data files. Appreciation and thanks also are extended to Rudy King, Rocky Mountain Research Station Statistician, and Chuck Bonham, Colorado State University, Department of Rangeland Ecosystem Science for providing statistical advice.

LITERATURE CITED

Ball, G.H., and D.J. Hall. 1967. A clustering technique for summarizing multivariate data. Behavioral Science 12:153-155.

Bement, R.E. 1969. A stocking-rate guide for beef production on blue-grama range. J. Range Manage. 22:83-86.

Benkobi, L., D.W. Uresk, G. Schenbeck and R.M. King. 2000. Protocol for monitoring standing crop in grasslands using visual obstruction. J. Range Manage. 53:627-633.

Coppock, D.L., J.K. Detling, J.E. Ellis and M.I. Dyer. 1983. Plant-herbivore interactions in a North American mixed-grass prairie. I. Effects of black-tail prairie dogs on interseasonal aboveground plant biomass and nutrient dynamics and plant species diversity. Oecologia 56:1-9.

del Morel, R. 1975. Vegetation clustering by means of ISODATA: Revision by multiple discriminant analysis. Vegetatio 29:179-190.

Ganguli, A.C., L.T. Vermeire, R.B. Mitchell, and M.C. Wallace. 2000. Comparison of four nondestructive techniques for estimating standing crop in shortgrass plains. Agronomy J. 92:1211-1215.

Heady, H.F., and R.D Child. 1994. Rangeland ecology and management. Westview Press, Boulder, CO. 519 pp.

High Plains Regional Climate Center. 2008. High Plains Regional Climate Center website (http://www.hprcc.unl.edu/products/home.htm – specifically http://www.hprcc.unl.edu/stations/index.php?action=metadata&network_station_id=3920 87). Long term monthly totals for Custer, South Dakota are from 1911 to 2008.

Hoffman, G.R., and R.R. Alexander. 1987. Forest vegetation of the Black Hills National Forest of South Dakota and Wyoming: a habitat type classification. Res. Pap. RM-276. Ft. Collins, CO: USDA, Forest Service, Rocky Mountain Forest and Range Experiment Station. 48 pp.

Holechek J.L., R.D. Pieper and C.H. Herbel. 1989. Range management: principles and practices. Prentice Hall, New Jersey 501pp.

Hooper, J.F., and H.F. Heady. 1970. An economic analysis of optimum rates of grazing in the California annual-type grassland. J. Range Manage. 23:307-311.

Mueller-Dombois, D., and H. Ellenberg. 1974. Aims and methods of vegetation ecology. John Wiley & Sons, New York. 547 pp.

Neter, J., W. Wasserman and W. H. Kutner. 1989. Applied linear regression models, 2nd ed. Irwin, Homewood, IL. 667 pp.

Orr, H.K. 1959. Precipitation and stream flow in the Black Hills. Station Paper Rm-44, Fort Collins, CO: U.S. Department of Agriculture Rocky Mountain Forest and Range Experiment Station. 25 pp.

Pase, C.P., and J.F. Thilenius. 1968. Composition, production, and site factors of some grasslands in the Black Hills of South Dakota. USDA Forest Service Research Note. RM-103, Rocky Mountain Forest and Range Experiment Station, Ft. Collins, CO 8 pp.

Robel, R.J., J.N. Briggs, A.D. Dayton and L.C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. J. Range Manage. 23:295-297.

SAS. 2003. SAS Institute Inc., Cary, NC, USA.

Severson, K.E., and C.E. Boldt. 1977. Options for Black Hills Forest owners: timber, forage, or both. Rangeman's J. 4:13-15.

SPSS. 2003. SPSS Base 12.0 for Windows User's Guide. SPSS Inc.703 pp.

Steel, R. G. and J. H. Torrie. 1980. Principles and procedures of statistics, 2nd ed. McGraw-Hill, New York 633 pp.

Uresk, D.W. and T.A. Benzon. 2007. Monitoring with a modified Robel pole on meadows in the central Black Hills of South Dakota. W. North Amer. Nat. 67:46-50.

Uresk, D.W., and T.M. Juntti. 2008. Monitoring Idaho Fescue grasslands in the Big Horn Mountains, Wyoming, with a modified Robel pole. W. North Amer. Nat. 68:1-7.

Vermeire, L.T., and R.L. Gillen. 2001. Estimating herbage standing crop with visual obstruction in tall grass prairie. J. Range Manage. 54:57-60.

Vermeire, L.T., A.C. Gangull and R. L. Gillen. 2002. A robust model for estimating standing crop across vegetation types. J. Range Manage. 55:494-497.

Volesky, J.D., W.H. Schacht and P.E. Reece. 1999. Leaf area, visual obstruction, and standing crop relationships on Sandhills rangeland. J. Range Manage. 52:494-499.

Wydeven, A.P., and R.B. Dahlgren. 1985. Ungulate habitat relationships in Wind Cave National Park. J. Wildlife Manage. 49:805-813.