Comparison of methods to estimate forage biomass in the Garvin Basin, south central Montana for use in forage allocation models
by Shilo Ann Comeau

A thesis submitted in partial fulfillment of the requirements for the degree of Masters of Science in Fish and Wildlife Management
Montana State University

Abstract:
Forage allocation models are used to allocate forage resources in areas where multiple ungulate species share the same range. In the Garvin Basin, south central Montana, forage allocation models were created to determine the number of cattle and elk that could be supported in the Garvin Basin. Allocation models were based on forage consumption, forage availability, and species distribution in the basin. To estimate the amount of forage available in the basin, 2 techniques were employed: 1) the Landsat 5 TM-based method and 2) the conventional exclosure-based method. There was no significant difference in the estimates for the entire basin obtained using either method for total or shrub biomass (total using Landsat-based =14 million kg ± 2 million kg, total using exclosure-based =15 million kg ± 439 thousand kg) (shrub using Landsat-based = 6 million kg ± 3 million kg, shrub using exclosure based = 4 million kg ± 1 million kg). However, there was a significant difference in the 2 estimates of herbaceous biomass with Landsat producing lower herbaceous biomass (herb using Landsat-based = 4 million kg ± 2 million kg, herb using exclosure-based =11 million ± 2 million kg). Estimates of biomass were used in forage allocation models to estimate a year-long carrying capacity for ungulates in the basin. The model that best represented the system of the basin estimated 2,979 elk at the current cattle stocking rate of 1,725 AUMs using the Landsat-based technique and 3,571 elk at 1,725 cattle AUMs using the exclosure-based method. Considering the elk population is exploited, I recommended that the population be maintained at an "intermediate level" from 1,000 to 1,800 elk at 1,725 catttle AUMs where recruitment should be the highest in the elk population.

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Shilo Ann Comeau

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

Forage allocation models are used to allocate forage resources in areas where multiple ungulate species share the same range. In the Garvin Basin, south central Montana, forage allocation models were created to determine the number of cattle and elk that could be supported in the Garvin Basin. Allocation models were based on forage consumption, forage availability, and species distribution in the basin. To estimate the amount of forage available in the basin, 2 techniques were employed: 1) the Landsat 5 TM-based method and 2) the conventional exclosure-based method. There was no significant difference in the estimates for the entire basin obtained using either method for total or shrub biomass (total using Landsat-based = 14 million kg ± 2 million kg, total using exclosure-based = 15 million kg ± 439 thousand kg) (shrub using Landsat-based = 6 million kg ± 3 million kg, shrub using exclosure based = 4 million kg ± 1 million kg). However, there was a significant difference in the 2 estimates of herbaceous biomass with Landsat producing lower herbaceous biomass (herb using Landsat-based = 4 million kg ± 2 million kg, herb using exclosure-based = 11 million ± 2 million kg). Estimates of biomass were used in forage allocation models to estimate a year-long carrying capacity for ungulates in the basin. The model that best represented the system of the basin estimated 2,979 elk at the current cattle stocking rate of 1,725 AUMs using the Landsat-based technique and 3,571 elk at 1,725 cattle AUMs using the exclosure-based method. Considering the elk population is exploited, I recommended that the population be maintained at an "intermediate level" from 1,000 to 1,800 elk at 1,725 catttle AUMs where recruitment should be the highest in the elk population.

INTRODUCTION

Background

Ungulates are generally large, long-lived herbivores that have low reproductive rates and high maternal investment (McCullough 1999). In temperate regions, free ranging ungulates adjust their diets according to the season (Feldhamer 1999), often migrating to energy- and nutrient-rich, seasonally available areas for growth and the accumulation of energy reserves (Houston 1982). In mountainous regions, wild ungulates often migrate between high elevation summer ranges and lower elevation winter ranges (Feldhamer 1999). This strategy affords full utilization of all suitable range (Houston 1982). In contrast, domesticated ungulates, such as cattle, only make major changes in seasonal ranges when managers allow them to do so (Kie et al. 1996). If ungulate herds, domestic or wild, become too abundant they have the potential to destroy natural forage plants on these ranges (Schmidt and Gilbert 1943). Consequently, managers seek to balance wild and domestic ungulate numbers with available forage resources (Schmidt and Gilbert 1943) by estimating a carrying capacity, i.e., the number of animals a habitat can sustain (Bailey 1934), and limiting herbivore numbers accordingly. Forage allocation models are used to allocate forage resources in areas where multiple ungulate species share the same range (Westfall et al. 1993). Through the use of these models managers can determine how many animals a system can support based on the available forage and forage requirements for each species.

The evaluation of habitat elements critical to sustaining populations and maintaining or increasing carrying capacity is essential to any estimate of carrying capacity (Lubbering et al. 1991). Data on vegetation density, cover, and biomass are often required by wildlife and land managers because such measures can be associated with forage availability and habitat carrying capacity (Higgings et al. 1996). Available forage biomass in the Garvin Basin, south central Montana, has been evaluated expressly for domesticated livestock (BIA 1969), and the number of cattle animal unit months (AUMs) allotted for the basin was derived with no consideration for the forage requirements of elk that winter in the basin (BIA 1969). For this study, an assessment of available forage biomass was completed and used to estimate the number of cattle AUMs and the number of elk that could be supported in the basin.

One method of directly estimating forage biomass is by clipping all the vegetation to ground level in sample plots of known area, and then weighing the wet or dry vegetation removed (Pearson et al. 1976, Cox and Waithaka 1989, Higgins et al. 1996). Mean biomass per unit area may then be estimated as the product of average biomass per plant and mean density of plants (Higgins et al. 1996). A standard for measuring the amount of forage biomass available for harvest by ungulates is the exclosure method, i.e., comparisons of vegetation amounts obtained from paired grazed and ungrazed plots (Litvaitis et al. 1996). These paired plots, selected for similarity in species composition and production, are established prior to the growing season. Vegetation in both plots is clipped at the end of the growing season, and biomass is recorded (Litvaitis et al. 1996). The mean from ungrazed plots will be multiplied by the number of units in the study area i.e., number of hectares, to estimate the total amount of forage biomass available. Means for grazed plots provide estimates of residual biomass; the difference in means is interpreted as the amount of biomass removed by ungulates. Commonly, such exclosure methods can be costly, time-intensive, and have large errors (Litvaitis et al. 1996). Furthermore, this method may inadequately estimate biomass for large areas because sample units are usually small (Porwal et al. 1996), representing a minuscule percentage of the pasture and may be subject to variance within the sample related to the time required for sampling rather than herbivore use.

Alternatively, satellite spectral data and conversions of these data have been employed to examine and derive biophysical attributes of earth surfaces (Yang et al. 1998). When electromagnetic energy strikes the earth's surface, 3 interaction results are possible: reflectance, absorption, or transmittance of energy (Lillesand and Kiefer 1999). Reflectance data of different wavelength bands can then be used to distinguish among soil, water, and vegetation (Lillesand and Kiefer 1999). Satellite image interpretation has been used to estimate biological variables such as vegetation cover, leaf area index, and biomass (Kasturirangan 1996, Hurcom and Harrison 1998, Lawrence and Ripple 1998). Vegetation indices have been developed from reflectance data used to estimate forage biomass (Lillesand and Kiefer 1999). Although these indices have been successfully applied at many locations, they have been problematic in semiarid and low-vegetation areas (Elvidge and Lyon 1985, Paruelo et al. 1997, Lawrence and Ripple 1998, Muldavin et al. 2001). Lawrence and Ripple (1998) demonstrated that bandwise multiple regression preformed better than vegetation indices in the low vegetation Mount St. Helens region.

They explained more variability in vegetation cover through decoupling because this allowed for the analysis and manipulation of individuals bands, whereas vegetation indices do not.

Ground-based reflectance measurements can be coupled with satellite reflectance data to assess vegetation biomass over a large scale in a short time period (Kasturirangan 1996, Hurcom and Harrison 1998, Elmore et al. 2000, Wylie et al. 2002). Multispectral radiometers (MSR) are used to collect ground-based spectral data associated with earth surfaces, including vegetation. The MSR measures radiation in different bands as it measures incident radiation in these bands. The ratio of these gives percent reflectance (Cropscan 2002). Finally, MSR reflectance measurements are used to estimate biomass. These biomass estimates are then regressed against satellite reflectance to assess the correlation between the two. By using this 2 step process, biomass measured directly from plots can be correlated to satellite reflectance values through the use of the MSR unit used to collect ground reflectance. If significantly correlated, satellite reflectance data can be used to estimate biomass on a "landscape scale" (Wylie et al. 2002).

Remotely sensed data present a number of advantages over other methods of forage biomass estimation. Satellite images can provide information about large tracts of land at less expense than required for the collection of other types of data, and digital data can be input directly into computers, thereby allowing rapid investigation and manipulation (Mack et al. 1997). Finally, this sampling technique may reduce the need for destructive vegetation sampling (Pearson et al. 1976, Wylie et al. 2002).

In my study, bandwise regression and vegetation indices were compared to obtain the strongest correlation between ground-based reflectance measurements and dry forage biomass clipped from circular plots. Next, bandwise regression and vegetation indices were used to test which method provided the strongest correlation between biomass estimates for "ground pixels" and satellite reflectance data for those pixels. I hypothesized that bandwise regression would explain more of the variation in forage biomass than vegetation indices because of the ability to analyze and manipulate individual band data.

Allocation models were created for the Garvin Basin using forage biomass estimates obtained through 2 techniques; 1) the conventional exclosure method and 2) combining ground-based reflectance measurements with satellite reflectance data. I tested the null hypothesis that forage biomass estimates derived from each method would not be statistically different. The model results were then used to establish an estimate of carrying capacity for ungulates in the Garvin Basin and to provide management recommendations to the Crow Tribal Game and Fish Department.

Objectives

The goal of my study was to estimate a year-long carrying capacity for ungulates in the Garvin Basin. The first objective was to compare forage biomass in the basin, estimated using exclosure plots and Landsat TM. My second objective was to create forage allocation models based on the estimates acquired for comparison.

STUDY AREA

The Garvin Basin, a nearly unaccessible, semiarid sagebrush grassland between the Bighorn and Pryor Mountain ranges of south central Montana, is located 40 km southeast of Billings, Montana (Fig. 1). The study area is approximately 17,749 ha, and elevations range from 1,177 to 1,829 m. The basin is roughly triangular in shape with the apex on the north where Big Bull Elk Ridge meets the Bighorn River. The east boundary is the west escarpment of the Big Bull Elk Ridge; the west boundary is the 110 to 171 m high escarpment at the east edge of the Yellowtail Reservoir; and the south boundary is Devils Canyon (BIA 1969). There are 3 semipermanent streams that drain the basin; Twenty Mile and Gyp Creek at the north end of the basin and Trout Creek in the extreme southern end (BIA 1969). The Garvin Basin is predominantly blanketed by big sagebrush (*Artemisia tridentata*) and silver sage (*Artemisia cana*) with a grass understory, while some of the steep ridges and slopes are covered by juniper (*Juniperus scopulorum*). The graminiod species of major importance within the basin are bluebunch wheatgrass (*Agropyron spicatum*), needle and thread (*Stipa comata*), Junegrass (*Koeleria pyramidata)*, and western wheatgrass (*Agropyron smithii*). Soils range from deep to very shallow, silty clay to sandy loams, but only 2% of the area is occupied by deep permeable soils and 12% by moderately permeable soils (BIA 1969). The climate of the basin is characterized by warm summers and cold winters. The daily temperatures ranges from -26°C to over 38°C (Anderson et al. 1987). Annual precipitation in the basin ranges from

20 cm to 30 cm (NRIS 2002).

In the fall, as many as 1,200 elk (*Cervuselaphus*) migrate annually into the basin and remain there until early spring (Cobell 2001). The current cattle AUM allocation is 1,725, and grazing is allowed between May and October (Hanley pers. commun.). The actual AUMs have varied over the past 3 decades. No cattle were grazed in the basin during the study period (2000-2001) and the only domestic livestock in the basin observed during my study were 5 trespass horses. Fewer than 80 mule deer (*Odocoileus heminous)* were seen in the basin in March of 2000 (Roybal 2000) and less than 10 in February of 2001 (Comeau, unpubl. data 2001).