USING COMPUTER SIMULATION TO ESTIMATE GRAZING CAPACITY AND BEEF PRODUCTION[1]

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Increased efficiency of red meat production is an important goal of livestock management that can be enhanced by properly applied rangeland improvement practices. However, the outcome of such improvements cannot always be predicted. A method of estimating potential grazing capacity and beef production would be a welcomed tool for ranchers and resource managers in selecting the kind and location of improvements. Such a method would also be helpful in coordinating livestock management with other rangeland activities. Toward this end, a computer model is being developed to simulate animal unit months (AUM's) of grazing, and pounds of beef production potentially available from specific sites in central Oregon. The objective of this report is to outline the structure, operation, and behavior of the preliminary model.

MODEL STRUCTURE

The structure and flow of the model is outlined in Figure 1. The model includes two main subroutines: one which calculates potential grazing capacity expressed as AUM's, and one which calculates potential beef production expressed in pounds. The model operates at 3 spatial and 5 temporal levels of resolution. Levels of spatial resolution are: pastures within ranches (or grazing allotments); resource units (mapping types) within pastures; and slope/distrance from water polygons within resource units (Figure 2). Levels of temporal resolution are: May 15-June 14; June 15-July 14; July 15-August 14; August 15-September 14, and September 15-October 14.

Operation of the model begins by calculating seasonal forage availability within each resource unit. Once determined, forage availability is compared to the dry matter forage requirement of a 1,000 pound animal unit to calculate AUM's of grazing potentially available. Seasonal forage availability is also compared to seasonal dry matter intake of a yearling heifer to estimate heifer unit days (HUD's) of grazing capacity as an intermediate step to estimating beef production. Next, average daily gain (ADG) of a yearling heifer is determined from daily intake of crude protein and digestible energy. Finally, potential beef production is calculated as the product of HUD's and ADG.

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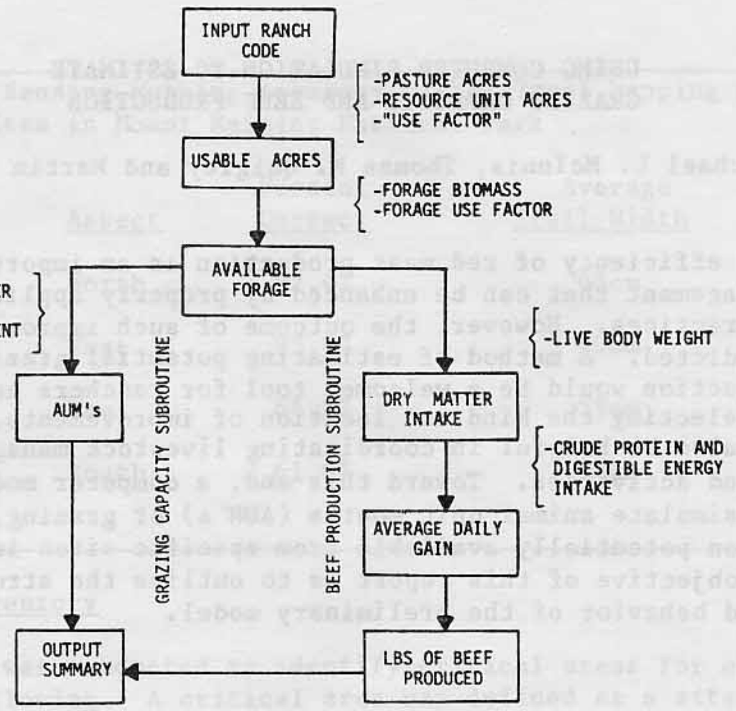

Figure 1. Flow diagram of grazing capacity and beef production model.

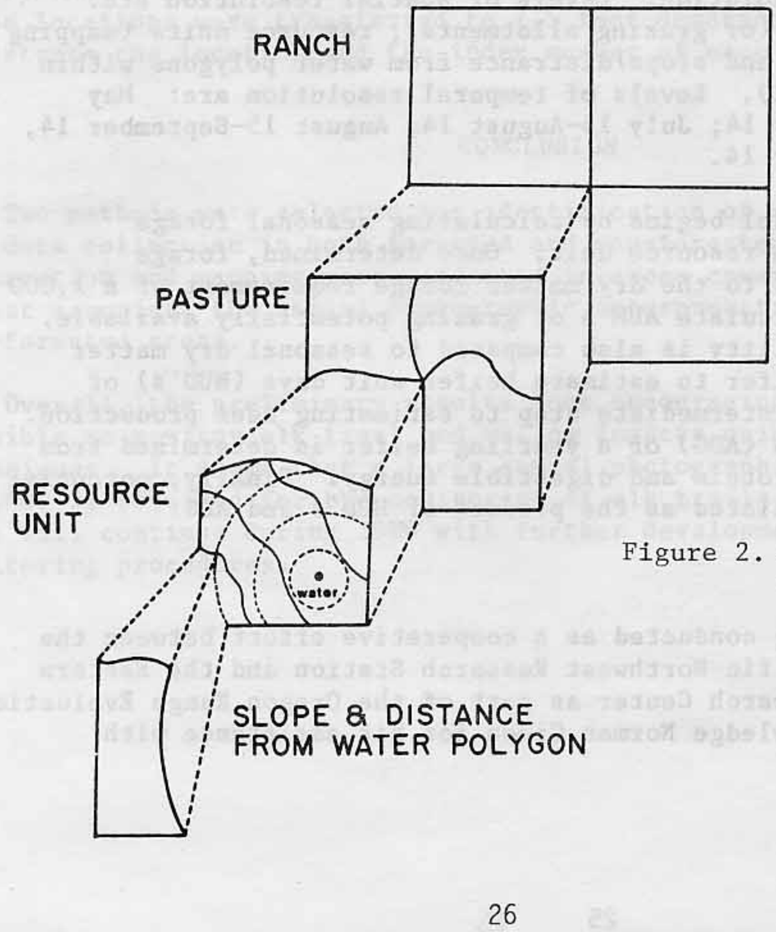

Figure 2. Levels of spatial resolution of model.

MODEL OPERATION

A. Grazing Capacity Subroutine

The core of the subroutine is the equation:

$$AUMn = \frac{(UA)\ (FB)\ (FUF)}{DMFR}$$

where AUMn is animal unit months at resolution "n"; UA is usable acres; FB is forage biomass; FUF is forage use factor; and DMFR is dry matter forage requirement.

Cattle use of a given area is especially influenced by its terrain (percent slope) and distance from water. Most research has shown forage utilization decreases as percent slope and distance from water increase (Gillen et al. 1984; Roath and Krueger 1982). An input file was created to accommodate classification of acres within each resource unit into 4 slopes, and 5 distance from water categories. Cattle "use factors" (Percent of the total area suitable for grazing) were estimated for each combination of slope and distance from water (Table 1). The model calculates usable acres (UA0 of each polygon by multiplying this use factor by the number of acres within the polygon. Standing crop biomass was measured by forage class (grass, forbs, and shrubs) within each resource unit at time of maximum production. Forage biomass (FB) in the core equation is the sum of grass, forb, and shrub biomass. A generalized growth curve was developed from published values to allow adjustment of forage biomass for each of the 5 grazing periods by ecosystem. The model calculates the amount of forage available to cattle as the product of forage biomass (FB) and a forage use factor (FUF0 which reflects the percent desirable utilization. The model allows input of any level of FUF, but we assumed 50% during periods of plant growth, and 65% after plant maturation. Because cattle show seasonal dietary preference for specific forage classes, a separate file was created to adjust amounts of grasses, forbs, and shrubs consumed during each of the 5 grazing periods within each ecosystem. Once calculated, the amount of forage thus available for grazing is compared to the dry matter forage requirement (DMFR) of a 1,000 pound animal unit for 30 days. This is assumed to be 2.5% of live body weight per day, or 750 pounds for one month.

Table 1. Estimated "use factors" for slope/distance from water polygons

DISTANCE FROM WATER (m)	PERCENT SLOPE (1) 0-5%	PERCENT SLOPE (2) 6-15%	PERCENT SLOPE (3) 16-45%	PERCENT SLOPE (4) 45+%
(1) 0-200m	100%	100%	90%	60%
(2) 201-400m	100%	100%	80%	50%
(3) 401-600m	100%	90%	70%	50%
(4) 601-1500m	90%	80%	70%	50%
(5) 1500+m	75%	60%	50%	40%

B. Beef Production Subroutine

Operation of this subroutine begins at the resource unit level by first dividing pounds of available forage by pounds of dry matter intake consumed by a heifer in one day. This value is multiplied by the average daily gain (ADG) of heifers to yield pounds of beef produced within the resource unit. Beef production within a given pasture is easily calculated as the sum of beef produced within the resource units of that pasture. The core equation is:

AVAILABLE FORAGE (lbs) / INTAKE (lbs/day) X ADG (lbs)

AVAILABLE FORAGE calculated by the model as described above is input into the beef production subroutine (Figure 1). Daily dry matter INTAKE is calculated as the product of live body weight and forage intake expressed as a percentage of live body weight. Live body weights of yearling heifers grazing forest and grassland communities in northeastern Oregon were obtained during each grazing period from 1977 through 1980. Corresponding values of forage intake expressed as a percentage of live body weight were obtained from Holechek and Vavra (1982). AVERAGE DAILY GAIN was calculated using the function given by Holechek (1980):

$$Y = 0.125A + 0.104B - 1.182 \times 2.2$$

where Y is ADG (lbs); A is crude protein intake (kg/day); and B is digestible energy intake (Mcal/day). Our values of crude protein and digestible energy intake are from Holechek et al. (1981).

MODEL BEHAVIOR

The model was used to estimate grazing capacity of resource units of 18 cooperating ranches in central Oregon. Values of actual grazing capacity were obtained through interviews with personnel of the Soil Conservation Service (SCS). Simulated values were divided by actual values for each resource unit to obtain an index of concordance (S/A Ratio). The S/A Ratio may vary from zero to an undefined positive value. A value of 1.0 represents perfect concordance; values less than 1.0 indicate simulated AUM's are less than observed; and values greater than 1.0 indicate simulated AUM's are greater than observed. We are presently calibrating the model, using a random selection of one half of the resource units for which we have data. The remaining resource units represent a "hold out" data set which will be used to validate the model once we are comfortable with results of the calibration phase.

Results of initial model calibration are illustrated in Table 2, in which seasonal S/A Ratios are pooled by ecosystem. S/A Ratios generally differ by ecosystems. Grazing capacity in Douglas-fir and larch ecosystems are underestimated. We believe this error is a reflection of input data rather than model performance. Forage biomass data were gathered from private and public forests, and pooled to obtain an adequate sample size for use in the model. Intensively managed timber stands were not included in biomass sampling. These sites were common in stands of privately-owned forests, and probably resulted in an increase of understory production and grazing capacity compared to less intensively managed forests. Pooling understory biomass from public and private lands which excluded intensively managed timber sites may have underestimated actual forage biomass within these ecosystems, resulting in conservative simulated AUM's. Simulated grazing capacity in juniper and mountain grassland ecosystems was higher than reported by SCS, especially on fair and poor condition rangeland. SCS estimates of potential AUM's were based only on production of perennial plants, whereas the model includes biomass of annual species. Therefore, simulated AUM's exceed SCS values on areas where annual plants composed a large proportion of total biomass production.

At the present stage of development, the beef production subroutine remains untried. Work is continuing on this portion of the model, and we expect to provide validation of its results using data collected from the Blue Mountain of northeastern Oregon.

Table 2. Mean S/A Ratio by Ecosystem

Ecosystem	S/A Ratio Mean	S/A Ratio S.E.	N (seasons)[a]
Douglas-fir	0.4	0.1	4
Ponderosa pine	1.0	0.1	5
Larch	0.8	0.1	4
Sagebrush	1.1	0.1	5
Juniper	1.2	0.1	5
Mountain grassland	1.2	0.1	5
Mountain meadow	1.1	0.1	5

[a] Douglas-fir and larch communities are not normally grazed during the first season (May 15-June 14).

SUMMARY

This paper outlines the structure, operation, and behavior of a preliminary computer model designed to simulate AUM's of grazing capacity and pounds of beef production potentially available from rangelands. The model operates at several levels of spatial resolution including resource unit (mapping type), pasture, and ranch. The model can provide estimates for each of 5 periods throughout a grazing season beginning in mid-May and lasting through mid-October. Driving variables are easily obtainable, and not data intensive. Although we are still in the calibration phase of model development, preliminary simulation results are encouraging. Future reports of the model should provide validation of grazing capacity and beef production simulation, as well as statistical analysis of results. Potential application of the model should assist land managers in predicting consequences of specific rangeland activities on red meat production.

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