TECHNICAL ARTICLE

Predicting beef cattle stocking rates and live weight gains on Eastern Oregon rangelands: Description of a model

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A simple deterministic model was developed to predict animal unit months (AUM's) and live weight gains of beef cattle grazing specific range types in eastern Oregon. The model can provide values for 3 levels of spatial resolution (pasture, mapping unit, and slope/proximity to water "cells" within mapping units) and 5 monthly periods from May 15 to October 14. Operation of the model begins by calculating forage availability as a factor of forage biomass, usable acres, and desired forage utilization. Grazing capacity (AUM's) is calculated by comparing forage availability with the dry matter forage requirement of a 1,000 lb animal unit for 30 days. Live weight gains are calculated by comparing forage availability to dry matter forage intake, crude protein intake, and digestible energy intake of yearling heifers. The model can be used in planning range improvements and coordinating livestock management with other rangeland activities.

Keywords: predicting systems, beef cattle, rangelands

Introduction

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 influence of such improvements on potential livestock grazing capacity and live weight gains cannot always be predicted. In 1976, the Oregon Range Evaluation Project was initiated to determine environmental and economic consequences of various rangeland management strategies (Sanderson *et al.* 1988a; Quigley *et al.* 1989). Toward this end, a simple method of estimating potential grazing capacity and beef production was desired. Data input requirements of existing models (Sanders and Cartwright 1979a; Sanders and Cartwright 1979b; Loewer and Smith 1986; Kahn and Spedding 1983; MacNeil, Skiles, and Hanson 1985) were beyond the scope of data collection opportunities of the Oregon Range Evaluation Project. Therefore, a method of estimating grazing capacity and beef production based on easily obtainable biological parameters was of importance. Such a method would be a welcomed tool for ranchers and resource managers in selecting economic improvements and coordinating livestock management with other rangeland uses.

The goal of this report is to outline the structure and operation of a deterministic, empirical model designed to predict (1) animal unit months (AUMs) of grazing capacity, and (2) pounds of beef production (live weight gain) potentially available from specific range sites within the Oregon Range Evaluation Project study area.

The study area consisted of 21 ranches in the Blue Mountain Physiographic Province (Franklin and Dyrness 1973) of eastern Oregon. Pastures within each ranch were mapped by "resource unit" (RU); a combination of ecosystem, productivity level, and condition class. Seven of the 34 ecosystems within the 48 contiguous states (Garrison *et al.* 1977) were considered in this study: Douglas fir (*Pseudotsuga menziesii*), ponderosa pine (*Pinus ponderosa*), larch (*Larix occidentalis*), sagebrush (*Artemisia spp*), juniper (*Juniperus spp*), mountain grassland, and mountain meadow. Productivity level is a relative measure of phytomass and was ranked as high, moderately high, moderately low, or low. Condition classes were based on vegetative cover, composition, and vigor. Condition classes in forested communities were: non-stocked, sapling, and saw-timber. Condition classes in non- forested communities were: good, fair, or poor. A detailed description of the study area was given by Sanderson *et al.* (1988a).

Model Structure

The model was written in FORTRAN 77 language and was developed on a model MV-4000 Data General computer. The model requires 25,000 bytes of memory for the source code, and 130,000 bytes of memory for execution. The model includes two main components: one which calculates potential grazing capacity expressed as AUMs per acre, and a second which calculates potential beef production expressed as pounds live weight (Figure 1).

The model operates at 3 levels of spatial resolution and yields output for each of 5 periods ("seasons") throughout a typical grazing year. Levels of spatial resolution are (1) pastures within ranches, (2) resource units within pastures, and (3) slope/proximity to water "cells" within resource units (Figure 2). Grazing is permitted from mid-May to mid-October on many public rangelands in the west. Thus, the simulated grazing year was assumed to extend from May 15 through October 14, and was divided into 5 seasons as follows: (1) May 15 - June 14; (2) June 15 - July 14; (3) July 15 - August 14; (4) August 15 - September 14; (5) September 15 - October 14. For convenience, ecosystems were grouped by plant phenology and date at which grazing normally begins (Table 1).

Model Operation

Overview

Operation of the model begins by calculating usable acres and seasonal forage availability within each RU (Figure 1). Once determined, forage availability is compared to the dry matter forage requirement of a 1,000 lb animal unit to calculate AUMs of grazing potentially available. Seasonal forage availability is also compared to seasonal dry matter intake of yearling heifers to estimate heifer unit days (HUDs) of grazing capacity as an intermediate step to estimating beef

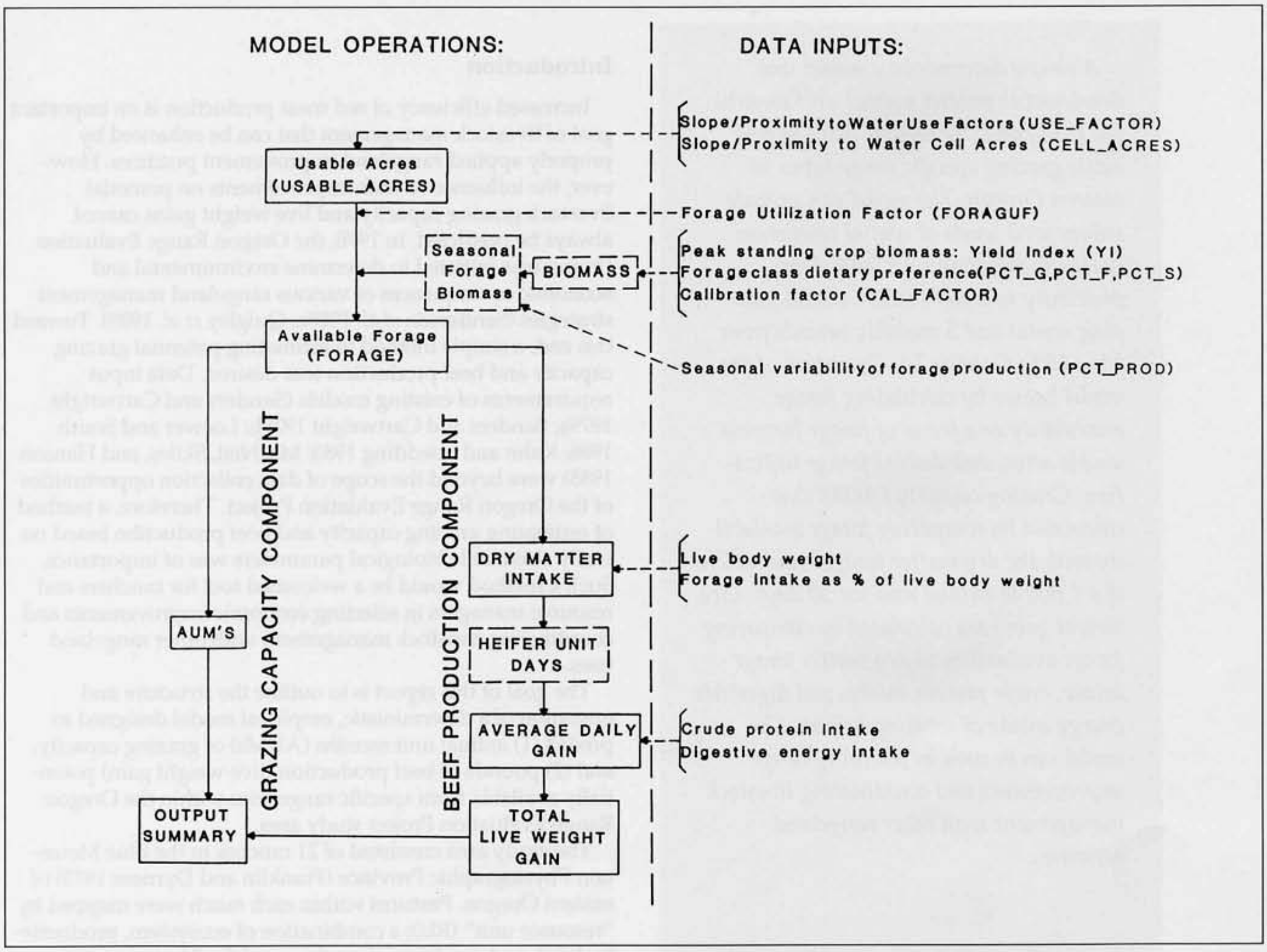


Figure 1. Flow diagram of grazing capacity/beef production model

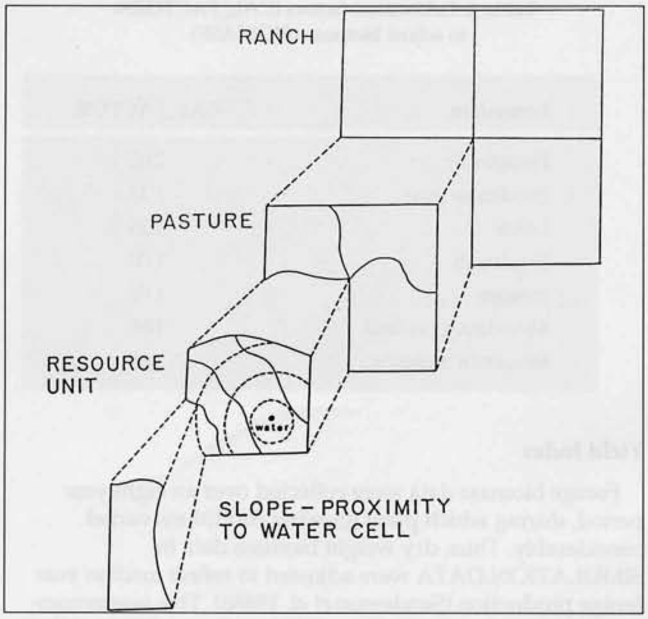


Figure 2. Levels of spatial resolution of model.

Table 1. Date grazing normally begins, growing seasons, seasons of peak standing biomass, and seasons of plant senescence by ecosystem groups.

Ecosystem Group/Ecosystem	Date Grazing Normally Begins	Growing Seasons	Season of Peak Standing Biomass	Seasons of Plant Senescence
Grassland	May 15	May 15-July 14	June 15-July 14	July 15-August 14
sagebrush				
juniper				
mountain grassland				
mountain meadow				
Ponderosa Pine	May 15	May 15 - September 14	July 15 - August 14	Sept. 15-Oct. 14
ponderosa pine				
Mixed Conifer Forests	June 15	May 15 - September 14	August 15 - September 14	Sept. 15-Oct. 14
douglas fir				
larch				

production. Next, average daily gain (ADG) of yearling heifers is determined from daily intake of crude protein and digestible energy. Finally, potential beef production is calculated as the product of HUDs and ADG.

Usable Acres

Cattle use of a given area is especially influenced by its topography and proximity to drinking water (Mueggler 1965, Cook 1966). Most research has shown forage utilization decreases as percent slope and distance from water increase (e.g. Roath and Krueger 1982, Gillen *et al.* 1984). The area within each RU was catagorized by 4 slope classes and 5 proximity to water classes using a geographic information system (Coe and Quigley 1986). The result was a set of unique slope/proximity to water cells within each RU. These cells are represented in the resource unit of Figure 2 with dashed lines as distance from water and solid lines as slope (Rice *et al.* 1983). Each cell was assigned a "use factor" (USE_FACTOR) to reflect cattle use as the percentage of acres within each cell likely utilized by cattle (Table 2). Thus, cells less than 200m from water with less than 5% slope were considered 100% utilized by cattle, while cells more than 1500m from water and greater than 45% slope were considered 40% utilized (Table 2). USE-FACTORS may be changed by other users if emperical data are available. The model calculates usable acres (USABLE_ACRES) of each cell as the product of USE_FACTOR and the number of acres within the cell (CELL_ACRES).

Table 2. Estimated "use factor" for slpoe/proximity to water cells reflecting percentage of acres within each cell utilized by cattle

Proximity to Water	Percent Slope			
	0-5%	6-15%	16-45%	45+%
0-200m	100%	100%	90%	60%
201-400m	100%	100%	80%	50%
401-600m	100%	90%	70%	50%
601m-1500m	90%	80%	70%	50%
+1500m	75%	60%	50%	40%

Available Forage

Available forage (lb/cell) is calculated as FORAGE by the equation:

$$FORAGE = FORAVA * USABLE\_ACRES$$

The variable FORAVA is calculated in a subroutine as a function of several parameters: (1) a "forage utilization factor" (FORAGUF) to express a desired level of forage utilization; (2) forage biomass at peak standing crop adjusted by dietary preference (BIOMASS); (3) a conversion factor from g/m^2 to lb/ac (8.92179); (4) a "yield index" (YI) to adjust forage biomass measurements to a common precipitation year; and (5) the factor PCT_PROD to account for seasonal variability of forage biomass.

Forage Utilization Factor

The variable FORAGUF is input by the user to adjust the desired level of forage utilization. FORAGUF may vary from 0-100%, but we assumed a value of 50% during seasons of plant growth, and 65% after plant senescence. These seasons vary by ecosystem (Table 1), but FORAGUF remains constant among forage classes (grasses, forbs, and shrubs).

Forage Biomass

Standing crop biomass within resource units was measured by forage class using 1.0 m^2 plots at time of maximum production (Sanderson *et al.* 1988b). The variable BIOMASS is defined by the equation:

BIOMASS = (GRASS *PCT_G) + (FORB * PCT_F) + (SHRUB * PCT_S)

where GRASS, FORB, and SHRUB are peak standing dry weight biomass (g/m^2) of grasses, forbs, and shrubs, respectively, and are entered into the model via the input file SIMULATION.DATA. Variables PCT_G, PCT_F, and PCT_S are factors that are input by the user via the file BIOMASS_PERCENTAGES to adjust dietary preference for forage classes. Grass is the primary forage class consumed by cattle (Skiles 1984), but in eastern Oregon forbs are readily utilized before they mature (Pickford and Reid 1948, Holechek *et al.* 1982a). However, use of shrubs is erratic. Collectively, shrubby species such as ninebark (*Physocarpus malvaceus*) and common snowberry (*Symphoricarpos albus*) may comprise values approaching 50% of cattle diets in forested communities (Holechek 1982b). Cattle grazing communities dominated by sagebrush, however, may consume less than 1% of this shrub (McInnis and Vavra 1987). BIOMASS_PERCENTAGES is a necessary variable since FORAGUF is a constant for all forage classes when, in fact, certain forage classes may not be utilized at that level. For example, in sagebrush or juniper communities FORAGUF may be defined as 50%, but cattle will not normally utilize 50% of available sagebrush biomass. To compensate, PCT_S may be defined as 1.0, so that with a value for FORAGUF of 50%, cattle will consume only 0.5% of sagebrush biomass. Our values for PCT_G, PCT_F, and PCT_S are shown in Table 3.

Table 3. File "BIOMASS_PERCENTAGES" to adjust utilization of grasses (PCT_G), forbs (PCT_F), and shrubs (PCT_S).

Ecosystem	PCT_G	PCT_F	PCT_S
Douglas fir	100	100	100
Ponderosa pine	100	100	100
Larch	100	100	100
Sagebrush	100	100	1
Juniper	100	100	1
Mountain grassland	100	100	100
Mountain meadows	100	100	100

BIOMASS can be further adjusted through a calibration factor (CAL_FACTOR):

BIOMASS = BIOMASS * CAL_FACTOR

The calibration factor can be determined through repeated observations of actual AUMs for given ecosystems. It represents the ratio of actual AUMs to estimated AUMs. We calibrated the model using AUMs actually observed over the period of the study for one half of the pastures with estimates obtained from the model when the CAL_FACTOR was set to 1.00. We found CAL_FACTORs varied by ecosystem, and ranged from 1.00 - 2.00 (Table 4). In our runs the forested ecosystems consistently estimated fewer AUMs than actually observed. This relates to the original production measurements obtained for these ecosystems. Measurements of production were not taken from disturbed (timber harvested or thinned) areas and thus resulted in an underestimate of actual production from the forested sites.

Table 4. Calibration factors (CAL_FACTORS) to adjust biomass (BIOMASS).

Ecosystem	CAL_FACTOR
Douglas fir	2.00
Ponderosa pine	1.43
Larch	1.25
Sagebrush	1.00
Juniper	1.00
Mountain grassland	1.00
Mountain meadow	1.00

Yield Index

Forage biomass data were collected over an eight year period, during which plant growing conditions varied considerably. Thus, dry weight biomass data in SIMULATION.DATA were adjusted to reflect median year forage production (Sanderson *et al.* 1988a). This was accomplished using the precipitation-biomass regression model of Sneva and Britton (1983) in which median year biomass was obtained by dividing actual biomass by a "yield index" (YI):

$$YI = -23 + 1.2\,X$$

where X was obtained by dividing crop-year precipitation of an area by its long-term median precipitation. Six weather stations were located on the study area, and assignment of precipitation data to specific pastures was based on horizontal distance, bearing, and elevation (Sneva and Calvin 1978). In low elevation ecosystems (sagebrush and juniper), the crop-year was defined as September through June. In all other ecosystems the crop-year extends into July or August. An input file (PRD.YIELD.INDICES) was provided to allow the user to adjust YI values (Table 5). Subroutine LOAD_YIELD_INDEX provides an "on-off" switch so the user may use biomass data in SIMULATION.DATA without the YI adjustment.

Seasonal Forage Biomass

Table 5. Yield Indices (YI) for two groups of ecosystems and six weather stations

Weather Station	Low Elevation Ecosystem[1]	High Elevation Ecosystem[2]
Austin	1.03	1.25
Dayville	1.18	1.56
John Day	1.16	1.56
Long Creek	1.72	2.00
Monument	1.21	1.60
Seneca	1.18	1.53

[1] Low elevation ecosystems are sagebrush and juniper.

[2] High elevation ecosystems are douglas fir, ponderosa pine, larch, mountain grassland, and mountain meadow.

Forage biomass was measured only during peak production. Because estimates of grazing capacity and beef production were desired for each season, corresponding estimates of seasonal standing crop were required. The factor PCT_PROD was created to allow the user to input seasonal standing biomass as a percentage of peak standing crop (0% > PCT_PROD < 100%). Seasonal biomass is then calculated as the product of PCT_PROD and BIOMASS. When empirical data are available for seasonal biomass, PCT_PROD becomes 100%. During the Oregon Range Evaluation Project peak production in "grasslands", "ponderosa pine", and "mixed conifer forests" occurred June 15 - July 14, July 15 - August 14, and August 15 to September 14, respectively. Other seasonal values were based on literature values, as shown in Table 6.

Grazing Capacity Component

Table 6. Seasonal PCT PROD (%) values for ecosystem groups.

		PCT PROD (%) by ecosystem group		
Season	**Dates**	**"Grasslands"**	**"Ponderosa Pine"**	**Forests"**
1	May 15 - Jun 14	65[1]	41[1]	23[2]
2	Jun 15 - Jul 14	100[1]	72[1]	47[1]
3	Jul 15 - Aug 14	95[2]	100[1]	80[1]
4	Aug 15 - Sept 14	90[2]	90[2]	100[1]
5	Sept 15 - Oct 14	85[2]	85[2]	90[2]

[1] Based on forage biomass measurements of Svejcar and Vavra (1985)
[2] Extrapolated values

Grazing capacity was defined by Heady (1975) as "the number of animals that produces the greatest returns without damage to physical resources in concert with other values received from the land", and is commonly expressed as AUMs. The model first calculates AUMs within each slope/proximity to water cell as the quotient of available forage within the cell and the dry matter forage requirement of a 1,000 lb animal unit (AU) for 30 days. The latter was assumed to be 2.5% of live body weight per day (Cordova *et al.* 1978), or 750 lbs for one month (Holechek and Vavra 1982). Because the model does not account for regrowth of plants following defoliation or fall precipitation, we assume each pasture is grazed during only one season throughout the grazing year. Given this, 750 lbs of forage per AUM is more realistic than the commonly used conversion of 1,000 lbs per AUM because shattering loss will be much less compared to yearlong grazing (Clary *et al.* 1974). The model provides output expressed in AUMs per acre by ecosystem.

Beef Production Component

Beef production (lbs. live weight) is based on performance of yearling heifers, and is estimated for each season throughout the grazing year as a function of forage quantity and quality (Figure 1). Operation of the subroutine begins at the resource unit level by calculating heifer unit days (HUDs) of grazing as an intermediate step. This is accomplished by dividing pounds of available forage by pounds of dry matter intake consumed by a heifer in one day. Next, HUDs are multiplied by average daily gain (ADG) of heifers to yield total live weight gain.

Dry Matter Intake

Daily dry matter intake (lbs) is calculated as the product of live body weight and forage intake expressed as a percentage of live body weight. Live body weights (lbs) of yearling heifers grazing forest and grassland communities on the Starkey Experimental Range in northeastern Oregon were obtained during each season from 1977 through 1980 (Table 7). Corresponding values of forage intake expressed as a percentage of live body weight (Table 8) were obtained from Holechek and Vavra (1982). A separate input file labeled "CP_DE_INTAKE" allows the user to change intake and live body weight values.

Table 7. Seasonal mean live body weights (lbs) of yearling heifers grazing forest and grassland communities on the Starkey Experimental Range, 1977-1980.[a]

		Live Body Weight (lbs)	
Season	**Dates**	**Forest[b]**	**Grassland[c]**
1	May 15 - Jun 14	715[d]	700[d]
2	Jun 15 - Jul 14	748	730
3	Jul 15 - Aug 14	787	779
4	Aug 15 - Sept 14	834	810
5	Sept 15 - Oct 14	854	822

a/ mean live body weight based on 20-26 individuals per season (Data on file, Eastern Oregon Agricultural Research Center, Burns, Oregon)
b/ "Forest" includes douglas fir, ponderosa pine, and larch ecosystems.
c/ "Grassland" includes sagebrush, juniper, mountain grassland, and mountain meadow ecosystems.
d/ Extrapolated values

Average Daily Gain

Average daily gain (lbs) achieved by yearling heifers was calculated using the function developed by Holechek (1980):

$$Y = (0.125A + 0.104B - 1.182) * 2.2046$$

where Y is ADG (lbs); A is crude protein intake (kg/day); B is digestible energy intake (Mcal/day); and 2.2046 is the conversion from kilograms to pounds. Our values for intake of crude protein and digestible energy are shown in Table 9, but may be changed by the user in the input file "CP_DE_INTAKE". When digestible energy is unknown, estimates may be calculated from *in vitro* dry matter digestibility (IVDMD) of forages using the equation of Rittenhouse *et al.* (1971):

$$DE\ (Mcal/kg) = 0.038 * (\%IVDMD) + 0.18$$

Table 8. Daily dry matter forage intake as a percentage of live body weight (Holechek and Vavra, 1982).

		Dry Matter Intake (% live body weight)	
Season	Dates	Forest[a]	Grassland[b]
1	May 15 - Jun 14	2.29[c]	2.42[c]
2	Jun 15 - Jul 14	2.29	2.42
3	Jul 15 - Aug 14	2.12	1.99
4	Aug 15 - Sept 14	1.94	1.84
5	Sept 15 - Oct 14	2.21	2.19

a/ "Forest" includes douglas fir, ponderosa pine, and larch ecosystems

b/ "Grassland" includes sagebrush, juniper, mountain grassland, and mountain meadow ecosystems.

c/ Estimated; assumed to be equivalent to value of subsequent season.

Table 9. Mean daily intake of crude protein and digestible energy of cattle grazing forest and grassland communities of Starkey Experimental Range (Holechek *et al.*, 1981).

Crude Protein Intake (kg/day)			
Season	Dates	Forest[a]	Grassland[b]
1	May 15 - Jun 14	0.75	0.75
2	Jun 15 - Jul 14	0.71	0.74
3	Jul 15 - Aug 14	0.68	0.58
4	Aug 15 - Sept 14	0.68	0.54
5	Sept 15 - Oct 14	0.74	0.66

Digestible Energy Intake (Mcal/day)			
Season	Dates	Forest[a]	Grassland[b]
1	May 15 - Jun 14	18.50	18.50
2	Jun 15 - Jul 14	16.93	18.30
3	Jul 15 - Aug 14	18.23	16.27
4	Aug 15 - Sept 14	15.93	14.10
5	Sept 15 - Oct 14	16.87	17.83

a/ "Forest" includes douglas fir, ponderosa pine, and larch ecosystems

b/ "Grassland" includes sagebrush, juniper, mountain grassland, and mountain meadow ecosystems.

Model Behavior

The model described here has been applied to 58,000 acres of private and 283,000 acres of public land as analyzed through the Oregon Range Evaluation Project (EVAL). One private land pasture with brush control treatments applied through EVAL is shown as an example of the application of this modelling technique. The 1023 acre pasture consisted of sagebrush (474 acres), juniper (154 acres), mountain grassland (305 acres), and mountain meadow (91 acres). Treatments included chemical control on 374 acres of sagebrush and mechanical control on 93 acres of juniper.

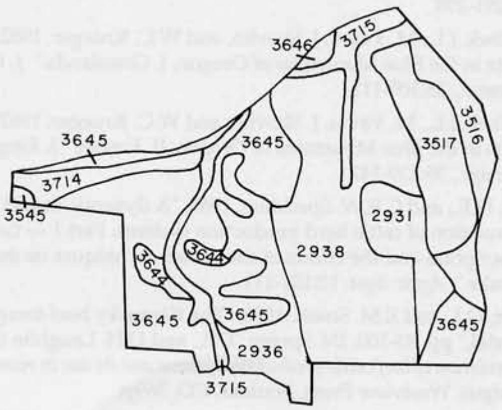
The pasture was mapped according to resource units (Figure 3a). This map was overlaid on a slope map (Figure 3b), and the resulting map was overlaid on a proximity to water map (Figure 3c). Areas of like catagories were summed to create the necessary input file to the model. Predictions of animal unit months of grazing available and beef production by each of 5 seasons were made by the model and averaged over the five seasons (Table 10).

The model was used to estimate grazing capacity of resource units of 18 cooperating ranches in eastern Oregon. Values of actual grazing capacity were obtained through interviews with personnel of the Soil Conservation Service (SCS). Simulated values (s) were divided by actual values (a) for each resource unit to obtain an index of concordance (S/A Ratio). The S/A Ratio may vary form zero to an undefined positive value. A value of 1.0 represents perfect concordance; values less than 1.0 indicate simulated AUMs are less than observed; and values greater than 1.0 indicate simulated AUMs are greater than observed. Results of initial grazing capacity estimates are illustrated in Table 11, in which seasonal S/A Ratios are pooled by ecosystem. S/A Ratios generally differ by ecosystem. 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 AUMs. Simulated grazing capacity in juniper and mountain grassland ecosystems was higher than reported by the SCS, especially on fair and poor condition rangelands. Estimates of potential AUMs made by the SCS were based on production of perennial plants only, whereas the model includes biomass of annual species. Therefore, simulated AUMs 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 component remains unvalidated. Work is continuing on this portion of the model, and we hope to provide validation of its results using data collected from the Blue Mountains of northeastern Oregon.

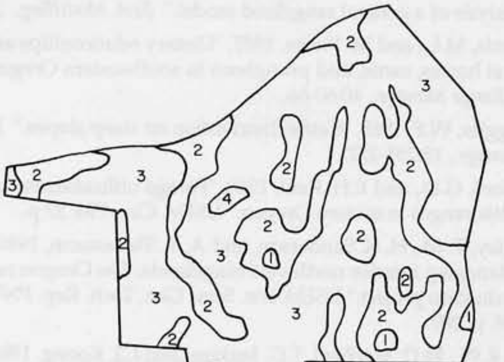
Conclusions

This report outlines the structure and operation of a deterministic, emperical model designed to predict animal unit months of grazing capacity and beef production (live weight gain) potentially available from specific range sites in eastern Oregon. The model utilizes easily obtainable data inputs, and should be of value to range managers. The model



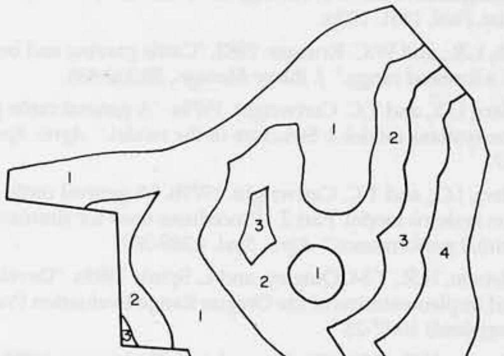
Resource Unit	Ecosystem	Productivity	Condition
2931	Sagebrush	mod. low	sprayed
2936	Sagebrush	mod. low	poor
2938	Sagebrush	mod. low	sprayed
3516	Juniper	high	poor
3517	Juniper	high	juniper control
3545	Juniper	low	fair
3644	Grassland	low	good
3645	Grassland	low	fair
3646	Grassland	low	poor
3714	Meadow	high	good
3715	Meadow	high	fair

Figure 3a. Example resource unit map.



Mapping Unit Number	Slope Category
1	0 - 5%
2	6 - 15%
3	16 - 45%
4	+45%

Figure 3b. Example slope category map.



Mapping Unit Number	Proximity Category
1	0 - 200m
2	201 - 400m
3	401 - 600m
4	601 - 1500m
5	+1500m

Figure 3c. Example proximity to water map.

can be used to estimate beef cattle stocking rates for environmental impact statements and coordinated resource management plans. Private ranchers will find the model useful to estimate beef production opportunities from specific range sites. This information could be used to select economic range improvements and substantiate proposed loans.

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References

Clary, W.P., M.B. Baker, P.F. O'Connell, T.N. Johnsen, and R. E. Campbell. 1974. "Effects of pinyon-juniper removal on natural resource products and uses in Arizona." USDA For. Serv. Res. Pap. RM-128. 28 p.

Coe, P.I., and T.M. Quigley. 1986. "Application of a geographic information system for the Oregon Range Evaluation Project, "pp. 88-98. *Proc. Geographic Information Workshop. Amer. Soc. for Photogrammetry and Remote Sensing.* Falls Church, VA.

Table 10. Simulated AUM's and live wieght gains from the example pasture averaged across five seasons

Resource Unit	Actual Acres	Usable Acres	Simulated AUM's	Simulated live weight gains (lbs)
2931	60.3	48.4	7	471.0
2936	99.6	85.6	8	540.2
2938	313.6	278.1	59	3815.9
3516	59.2	43.7	4	290.7
3517	92.7	71.4	14	919.6
3545	2.0	1.8	<1	10.7
3644	17.4	15.4	1	72.7
3645	280.7	241.9	18	1190.4
3646	6.5	6.1	<1	21.5
3714	32.1	30.3	37	2373.0
3715	58.8	55.5	23	1519.9
Totals	**1022.9**	**878.2**	**171**	**11,225.6**

Table 11. Mean S/A Ration by Ecosystem.

ECOSYSTEM	S/A Ratio Mean	S.E.	N (season)[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).

Cook, C.W. 1966. "Factors affecting utilization of mountain slopes by cattle." *J. Range Manage.*, 19:200-204.

Cordova, F.J., J.D. Wallace, and R.D. Piper. 1978. "Forage intake by grazing livestock: a review." *J. Range Manage.*, 31:430-436.

Franklin, J.F., and C.T. Dyrness. 1973. "Natural vegetation of Oregon and Washington." USDA For. Serv. Gen. Tech. Rep. PNW-8. 417 p.

Garrison, G.A., A.J. Bjugstad, D.A. Duncan, M.E. Lewis, and D.R. Smith. 1977. "Vegetation and environmental features of forest and range ecosystems." *USDA For. Serv. Agric. Handbk.* 475. 68 p.

Gillen, R.L., W.C. Krueger, and R.F. Miller. 1984. "Cattle distribution on mountain rangeland in northeastern Oregon." *J. Range Manage.*, 37:549-553.

Heady, H.F. 1975. *Rangeland Management*. McGraw-Hill Co., New York. 460 p.

Holechek, J.L. 1980. "The effects of vegetation type and grazing system on the performance, diet, and intake of yearling cattle." Ph.D. Diss., Oregon State Univ., Corvallis. 247 p.

Holechek, J.L., and M. Vavra. 1982. "Forage intake by cattle on forest and grassland ranges." *J. Range Manage.*, 35:737-741.

Holechek, J.L., M. Vavra, and J. Skovlin. 1981. "Diet quality and performance of cattle on forest and grassland range." *J. Anim. Sci.*, 53:291-298.

Holechek, J.L., M. Vavra, J. Skovlin, and W.C. Krueger. 1982a. "Cattle diets in the Blue Mountains of Oregon, I. Grasslands." *J. Range Manage.*, 35:109-112.

Holechek, J.L., M. Vavra, J. Skovlin, and W.C. Krueger. 1982b. "Cattle diets in the Blue Mountains of Oregon, II. Forests" *J. Range Manage.*, 35:239-242.

Kahn, H.E., and C.R.W. Spedding. 1983. "A dynamic model for the simulation of cattle herd production systems: Part 1 — General description and the effects of simulation techniques on model results." *Agric. Syst.* 12:101-111.

Lower, O.J., and E.M. Smith. 1986. "The Kentucky beef-forage model," pp. 63-100, IN: Spreen, T.H., and D.H. Laughlin (eds.). *Simulation of beef cattle production systems and its use in economic analysis.* Westview Press, Boulder, CO. 269p.

MacNeil, M.D., J.W. Skiles, and J.D. Hanson. 1985. "Sensitivity analysis of a general rangeland model." *Ecol. Modelling.* 29:57-76.

McInnis, M.L., and M. Vavra. 1987. "Dietary relationships among feral horses, cattle, and pronghorn in southeastern Oregon." *J. Range Manage.*, 40:60-66.

Mueggler, W.F. 1965. "Cattle distribution on steep slopes." *J. Range Manage.*, 18:255-257.

Pickford, G.D., and E.H. Reid. 1948. "Forage utilization on summer cattle ranges in eastern Oregon." USDA Circ. 796. 27 p.

Quigley, T. M., H. R. Sanderson, and A. R. Tiedemann, 1989. "Managing interior northwest rangelands: The Oregon range evaluation project." USDA For. Serv. Gen. Tech. Rep. PNW-GTR-238, p. 207.

Rice, R.W., M.D. MacNeil, T.G. Jenkins, and L.J. Koong. 1983. "SPUR livestock component." pp. 74-87. In: Wright, J.R. (Ed.). 1983. "SPUR — Simulation of production and utilization of rangelands: A rangeland model for management and research." *U.S.D.A., Misc. Publ.* 1431. 120p.

Roath, L.R., and W.C. Krueger. 1982. "Cattle grazing and behavior on a forested range." *J. Range Manage.*, 35:332-338.

Sanders, J.O., and T.C. Cartwright. 1979a. "A general cattle production systems model. I: Structure of the model." *Agric. Syst.* 4:217-227.

Sanders, J.O., and T.C. Cartwright. 1979b. "A general cattle production systems model. Part 2 - Procedures used for simulating animal performance." *Agric. Syst.* 4:289-309.

Sanderson, H.R., T.M. Quigley, and L. Spink. 1988a. "Development and implementation of the Oregon Range Evaluation Project." *Rangelands* 10:17-23.

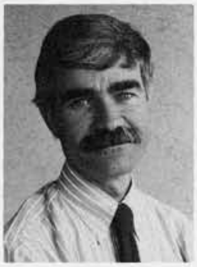
Sanderson, H.R., T.M. Quigley, and A.R. Tiedemann. 1988b. "Response of herbage and browse production to six range management strategies." *Rangelands* (in press).

Skiles, J.W. 1984. "A review of animal preference," pp. 153-213. In: Natl. Resour. Counc./Natl. Acad. Sci., *Developing strategies for rangeland management*. Westview Press. Boulder, CO. 2022 p.

Sneva, F.A., and C.M. Britton. 1983. "Adjusting and forecasting herbage yields in the intermountain big sagebrush region of the steppe province." Agric. Exp. Sta. Bull. 659. Oregon State Univ., Corvallis. 61 p.

Sneva, F.A., and L.D. Calvin. 1978. "An improved Thiessen grid for eastern Oregon: an interstation correlation study determining the effect of distance, bearing, and elevation between stations upon the precipitation correlation coefficient." *Agric. Meteor.*, 19:471-483.

Svejcar, T., and M. Vavra. 1985. "Seasonal forage production and quality on four native and improved plant communities in eastern Oregon." Agric. Exp. Sta. Tech. Bull. 149. Oregon State Univ., Corvallis. 24 p.



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