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AN ASSESSMENT OF COW WINTER FEEDING REGIMES USING A NET ENERGY BASED BIOPHYSICAL-ECONOMIC SIMULATION MODEL

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ABSTRACT

Three alternative winter feeding regimes (rake-bunch hay, range grazing, and meadow grazing) for mature spring calving cows were assessed and compared to baled hay feeding using a biophysical-economic simulation model. The objectives of the study were to (1) determine the most profitable and managerially feasible alternatives to baled hay feeding, and (2) lay a foundation for the development of a generalized spreadsheet simulation to assess future beef cattle management strategies. The model simulates relationships between the physiological status and nutritional requirements of the cow, the forage base, and effects of the physical environment on animal foraging success and metabolism. Cow monthly winter weight changes are entered into regression equations to yield calving and conception rates. The conception rate and calving rate equations had adjusted R^2 of 0.80 and 0.45, respectively. An economic subroutine was used to convert cow performance and forage utilization into ranch income statements to yield total and per cow net returns. Risk under each alternative was introduced by varying the climatic component using four winter scenarios ranging from mild to very severe winters. The results suggest that rake-bunch hay and range grazing regimes reduce wintering costs and increase ranch incomes. Expected net returns per cow for rake-bunch hay and range-grazing were $48 and $53 higher, respectively, than expected returns to the baled hay regime. Meadow hay grazing was not a feasible alternative. Expected returns per cow were $33 less than the baled hay system. Expected returns for range grazing may have been overstated given study assumptions and data limitations.

Introduction

A major goal in agricultural research is to predict beef cattle performance given variable feed resources and changing environmental conditions. Simulation has proven to be a effective method for predicting animal performance. Linked to an economic package, simulation serves as a powerful decision making tool when assessing beef production systems. In addition, simulation is helpful in identifying areas of weak understanding and generating hypotheses for further research.

A number of beef production models have been developed over the past two decades. These range from site specific to generalized models, either using a net energy or voluntary forage intake based format. All share similar pattern's of analysis. First, the production system being assessed is identified. Then a biological model is constructed which mathematically describes the system. After performing the simulation, costs of the production system are computed and output is valued, yielding estimated returns to the production system (Denham and Spreen, 1984).

In general, the structure of net energy simulation models are based upon Lofgreen and Garrett's (1968) system of equations estimating net energy requirements of cattle. One of the earliest models to incorporate the net energy system within its framework is the Texas A&M Beef Production Model (TAMU) developed by Sanders and Cartwright (1979b). The Kentucky Beef-Forage model is another beef simulation based upon the net energy system (Loewer and Smith, 1986). Both models are accompanied by fairly extensive economic packages.

The simulation model constructed for the purposes of this study also uses a net energy based system of equations. The purpose of the study was to assess the economic and managerial feasibility of three alternative winter feeding programs for cattle operations in the Harney Basin of Oregon. The main objective was to identify from the assessment those alternatives that have the greatest potential to increase returns above variable costs to a typical cow-calf operation found in the Basin. The three feeding alternatives evaluated include strip grazed rake-bunch hay, strip grazed uncut native meadow, and range grazing. These alternatives were compared to baled hay feeding, the prevalent winter feeding practice of the region. A second objective of the study was to lay a foundation for the development of a generalized spreadsheet simulation to assess beef cattle management strategies in eastern Oregon.

Simulation Model Overview

The prototype winter feeding beef simulation model integrates a system of six subroutines to yield information on cow reproductive performance, cattle production, forage utilization, and economic valuations for each feeding program. The subroutines include; (1) estimation of effective air temperature and snow depth influence on forage utilization; (2) determination of forage availability and quality; (3) estimation of cow nutritional requirements, intake, and monthly weight changes; (4) measurement of cow reproductive performance; (5) determination of herd production and forage utilization; and (6) calculation of the net returns to each feeding alternative. The simulation is conducted in weekly intervals over a five month winter period (October - February). The focus in this paper is on the cow nutrition, cow reproductive, climatic, and economic subroutines.

Cow Nutrition and Reproductive Performance

The main purpose of the simulation's biological component is to estimate reproductive performance of mature brood cows. For the rake-bunch hay, standing meadow, and baled hay alternatives this is accomplished by generating weekly weight changes in the brood cows, aggregating weekly weight changes into monthly weight changes, and finally fitting the monthly weight changes into regression equations predicting cow calving and conception rates. Weight changes in wintering cows are found by comparing the animals daily nutritional requirements versus the cows estimated daily nutritional intake. For the range grazing alternative, calving and conception rates are estimated directly from field data. In the simulation, calving and conception rates are assumed to be 97 percent and 88 percent respectively, for mild and average winters. During the severe and very severe winters the calving and conception rates are assumed to be 96 percent and 86.5 percent.

Cow net energy maintenance requirements are estimated using an modified TAMU equation. The equation adjusts for effective air temperatures calculated in the climatic subroutine, and for cow condition. To account for cow condition, the weekly metabolic weight of the cow is compared with an ideal metabolic weight based on assumed cow type and frame size.[2] The modified TAMU equation is:

(1) $NE_m = a \times (W^{0.75}) \times [(WM/W)^{0.5}]$

where

NE_m = Net energy for maintenance in Mcal/day
a = 0.077 x (0.0007 x [20 - T]), this is the equations temperature correction factor
T = effective air temperature, (C°)

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[2] This metabolic weight corresponds to an average sized Hereford, Hereford-Angus beef cow common to western ranges. A 480 kilogram body weight assumes a fat content of 25% (Sanders and Cartwright, 1979b).

W = live weight of the cow, (kg.)
WM = ideal metabolic weight, (kg.)

Energy requirements of pregnancy are estimated using an NRC equation (NRC, 1984). The equation estimates requirements based on the expected birth weight of the calf and the day of gestation. The model assumes a birth weight of 34 kilograms (75 lbs.), which approximates the average calve birth weights recorded during the Squaw Butte feeding trials.[3] The equation used is as follows:

(2) $NE_p = [CW \times (0.0149 - .0000407 \times t) \times e^z]/1000$

where

NE_p = Net energy of pregnancy, Mcal/day
CW = Calf birth weight, (kg.)
t = Day of pregnancy
e = Natural log, 2.714
z = $(0.05883 \times t) - (0.0000804 \times t^2)$

Following estimation of cow nutritional requirements, the subroutine calculates nutritional intake based on assumptions made on cow dry matter forage intake for each alternative. Cow metabolic weight change is determined by subtracting energy requirement computations from energy intake estimates, providing a measure of an animals energy surpluses or deficiencies. If an energy surplus exists cows are assumed to gain weight at a rate of one kilogram per 8.0 Mcal of excess energy (NRC, 1984).[4] If an energy deficiency is present cows are assumed to lose weight at the rate of one kilogram per 6.0 Mcal of energy. This figure represents the amount of energy the cow obtains from catabolizing body fat reserves to serve as an energy source during periods of energy deficiency (Reid and Robb, 1971; Moe et al., 1971; Mautz et al., 1976).

Conceptus weight gain is obtained directly from empirical measurements (Salisbury and Van Demark, 1961). Pregnancy weight gain is added to the cows ending metabolic weight to determine the cows total weight. Percentage monthly weight changes are computed and used in determining the calving and pregnancy rates of the cow herd. Weight changes are determined by taking beginning and ending monthly body weights and calculating the percentage change in cow body weight.

Calf crops and conception rates in the simulation are used to measure productive performance of the brood herd. These two determinants of herd performance provide information used in calculating economic returns to the ranch operation and to assess the relative merits of management alternatives.

The rake-bunch hay, standing meadow, and baled hay feeding strategies use percentage changes in cow winter monthly body weights to determine the herd's calving rate in the spring as well as conception rate in the summer breeding season. Based upon experimental data for the Squaw Butte feeding trials, regression equations were developed to measure calving and conception rates for cow herds placed on these particular feeding programs. The data used in the regressions consisted of pooled individual cow data. The aggregated cow herd data is composed of percentage monthly weight changes, herd calving rates, and herd conception rates in each of the three winters covered during the experimental period.

The rationale for constructing these equations is derived from empirical observation linking cow reproductive performance with nutritional aspects of the diet. Empirical evidence demonstrates that cows losing significant levels of weight (and condition) during gestation suffer reduced calf crops and conception rates (Wiltbank et al., 1964; Bellows et al., 1978). Results from the winter feeding trials conducted at Squaw Butte indicate that cows losing condition or weight suffer reduced calf crops and conception rates.

The equation used to estimate calving rate (CA) regressed trial herd calving rates against percentage monthly weight changes of the cows. Using ordinary least squares corrected for autocorrelation, the equation derived to predict calf crop percentage is:

(3) $CA = 94.947 + (1.095 * Nov) + (1.026 * Dec) - (0.522 * Feb)$

where

Nov = November percentage weight change
Dec = December percentage weight change
Feb = February percentage weight change

T-statistics for the coefficients were significant at 0.10. The R^2 of the regression was 59.4, but after adjustment fell to 45.0, indicating a fairly high degree of variance in the results.

The equation used to estimate conception rates regresses conception rate against the estimated calving rate, and winter percentage weight changes. Using ordinary least squares corrected for autocorrelation, the equation found to predict conception rates is:

(4) $Preg = 149.85 - (0.801 * CA) + (0.793 * Oct) + (3.761 * Nov) + (2.938 * Dec) + (2.856 * Jan) - (2.536 * Feb)$

where

CA = calving rate

Oct, Nov, Dec, Jan, Feb represent percentage monthly weight changes of the cow.

The t statistics of the coefficients are all significant at the 0.05 level. The R^2 of the regression is 90.2 and the adjusted R^2 is 80.6.

Climatic Variables

Four weather scenarios are used in the simulation, describing a range of winter climate conditions found in the Harney Basin. Scenarios were developed using (1) historical snow depth level, average daily temperature, and wind velocity data covering a 37 year period between 1950-1987; and (2) assumptions made regarding maximum snow depth levels permitting cattle to feed. The scenarios were composed of winters representing mild, average, severe, and very severe climate conditions. For the meadow and range grazing alternatives, scenarios are based upon the number of weeks cows were unable to access the primary feed source (meadow or range) due to snow conditions. In all the scenarios the rake-bunch hay and baled hay alternatives are unaffected by snow depth levels.

Empirical evidence and practical observation demonstrate that snow covered range or pasture inhibit or prevent cows from acquiring sufficient amounts of forage to meet nutritional requirements (Malechek and Smith, 1974; McCormack, 1988; and Senft et al., 1985). Estimates of when snow depth levels inhibit forage acquisition vary from as low as 13 centimeters on open meadow, to almost 30 centimeters on rangelands, and over 71 centimeters on rake-bunched hay feed grounds (Turner, 1988; Carr, 1988). Assumptions regarding minimum snow depth levels and the ability of cattle to forage are made for each of the alternatives. Cows placed on range for the winter are assumed to be prohibited from feeding on range grasses when snow depth levels exceed 20.3 centimeters. Cows feeding on standing meadow are assumed to be affected when snow depth levels exceed 12.7 centimeters.

Temperature and wind velocity combine to yield effective air temperatures and are used to estimate weekly cow net energy requirements. Temperatures below 20 C° produce an effective air temperature (EAT) or wind-chill that increase cow maintenance energy requirements (Ames and Insley, 1975; Ames 1980; Young, 1981). To measure effective air temperatures, the model uses Ames' equation for cows in heavy winter coat (Ames, 1988):

(5) $EAT (C) = (0.996 \times T) - (0.811 \times W) + (0.028 \times W^2) - (0.00077 \times W^3)$

where

T = dry bulb air temperature (C°)
W = wind velocity (mph)

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[3] The Squaw Butte branch of the Oregon State University Experiment Station is located in the Harney Basin. Winter feeding trials have been conducted since the 1982.

[4] Thin nonlactating mature cows are estimated to gain weight at rates of 5.5 and 7.5 Mcal/kg (NRC, 1984). Cows in the model are assumed to be in good condition entering the winter program. Therefore it is assumed that gains occur at a higher energy level of 8.0 Mcal/kg.

In the model an effective air temperature is adjusted only when wind velocities exceed three miles per hour. Temperatures are also used to adjust forage quality factors in the model. This adjustment for forage net energy and protein contents uses the following equational relationship (NRC, 1981):

(6) $A = B + B \times [C_r \times (T - 20)]$

where

- A = is the value adjusted forage factor [net energy (Mcal), and crude protein, (CP)]
- B = forage component value in Mcal or CP
- C_r = forage correction factor
- T = dry bulb air temperature in degrees C

Each weather scenario is assigned a probability of occurrence based on the historical record. Range and meadow grazing alternatives use probabilities of snow depth level in their scenarios, and the rake-bunch and baled hay alternatives the temperature probabilities.

Economic Assessment

The economic subroutine uses a set of partial budget statements to calculate net returns above variable costs per cow. Production risk is introduced into the simulation by the probabilities assigned to the weather scenarios. Previous studies have used weather condition probabilities to assess production risks to beef operations (Beck et al., 1982; Parsch et al., 1986; Reeves et al., 1974). In the study, probabilities assigned to each scenario are integrated with corresponding economic valuations (i.e. scenario net returns) to yield expected net returns to each feeding program. Expected net returns are estimated by the following equation;

(7) $ER = (Pm \times Rm) + (Pa \times Ra) + (Ps \times Rs) + (Pv + Rv)$

where

- ER = expected net return of alternative
- P = probability
- R = scenario net return
- m = mild winter
- a = average winter
- s = severe winter
- vs = very severe winter

Results and Discussion

Analysis of the results indicates that raked-bunched hay is the best alternative to baled hay feeding. Expected net returns to the rake-bunch hay alternative are $283, $48 per cow higher than the baled hay program (Table 1). This results from a substantial reduction in wintering costs under the rake bunch alternative, while cow reproductive factors and cattle production are essentially identical to the baled hay alternative. Management of the winter operation is simplified due to reduced labor effort. The ranch operator spends over 32 hours less per week managing the brood herd on rake-bunch regimes than on feeding baled hay.

Results from the simulation suggest that range grazing also is a promising alternative to baled hay. Expected returns to the range grazing regime were $288 per cow, $53 dollars greater than the baled hay system (Table 1). Winter costs varied depending on weather severity but under all scenarios net returns to the range regime remained higher than under the baled hay system. Management of the operation varies in intensity depending upon winter severity as measured by weekly labor input. In general, management effort is less than in the baled hay regime except under the most severe winter conditions. However in all scenarios labor input for the range grazing regime are substantially higher than labor input for the rake-bunch system.

The meadow hay alternative generated expected net returns of $202 per cow, $33 below the baled hay feeding regime (Table 1). Low expected returns to the meadow grazing system were a result of high winter costs combined with poor cow reproductive performance relative to the other alternatives. Consequently, the meadow hay system is not a feasible alternative for operators in the Harney Basin.

Expected returns to the range system may be overstated due to study assumptions and data limitations regarding cattle performance. Only two years (1986-1988) of field data were available limiting the number of observations made. Since no severe weather events occurred during the two years, weather effects on foraging success and ultimately on reproductive success under these conditions were lacking.

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Table 1. Expected net returns, winter cost, conception rate, calving rate, and weekly labor.

Feeding Regime	Expected Net Return	Winter Cost	Conception Rate	Calving Rate	Weekly Labor
	(dollars/cow)		------ % ------		(hrs)
Range	$288	$54 - 90	88.0	97.0	11 - 36
Rake-bunch	283	26	89.0	98.7	0.5 - 2
Baled hay	235	66	89.0	98.7	34
Meadow	202	44 - 62	73.0	93.5	14 - 26