Bio-economic evaluation of stocking rate and supplementary feeding of a beef herd

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Abstract

The effect of varying price ratios between liveweight and supplementary feed on the optimum stocking rate (SR) of a beef herd on range is analyzed in relation to the net value of weaned calf live weight. While the basis for determining optimum stocking rate is generally the value of production and costs per unit area, the animal performance per se is often a major management criterion, especially where the capital investment in livestock is high and where risk avoidance is an important consideration. Consequently, equations expressing the net value of beef production per unit of land and per animal unit are formulated as a function of SR. Parameter values for the equations were taken from a grazing trial conducted in the Galilee in Israel where a beef herd was maintained yearlong on native range for 5 years at 3 different SR's, 0.50, 0.67, and 0.83 cows/ha. The animals were supplemented ad libitum with poultry litter during the dry summer months. During the transitional period between the opening rains and range readiness, poultry litter was enriched with 20% barley grain. In addition, straw was given at an average rate of 80 to 375 kg/ha in the intermediate and highest stocking rates.

Over the range of SR's studied, it was shown that when supplementary feed and other per animal costs are high, net value of production per unit area of range *declines* with SR even though total production increases. On the other hand, when fixed range and management costs are high, the net economic benefit per cow *increases* with SR even though production per cow decreases. It is concluded that the optimum SR for a given situation depends not only on the input/out price ratios but also on the criterion for evaluating economic value that is most revelant to the manager.

Key Words: range economics, weaned liveweight, poultry litter

The relation between stocking rate effects on production per cow and per unit area have been widely studied (Hart 1972, 1978; McMeekan 1959; Morley 1981; Quigley et al. 1984) and the shape of the curves relating these factors is well documented (Harlan 1958, Hart 1972, Jones and Sandland 1974). As a rule, production per cow tends to decline as SR increases above a critical level, and production per unit area increases up to a maximum and then declines when greater numbers no longer compensate for reduced production per animal (Wilson 1986).

The management implications of these biological relationships depend on many factors that include not only the cost of all the inputs necessary for production but also on attitudes to risk (Thompson 1975) and on whether the main concern of the manager is the return to capital invested in livestock, or in total net income from the herd, or some other goal. Where animals are the main capital investment, maximum animal performance is often a central management criterion and will be achieved with lower stocking rates within the realistic range. In such a case the fixed pasture and management costs will affect the evaluation of net economic benefit per animal. However, in many cases, if not in most, the main criterion for determining optimum stocking rates is the net return for the operation as a whole. This is reflected in the net return per unit area, at least when the available area of land is fixed (Jameson et al. 1974). Where supplementary feeding of the beef herd is important, it complicates the determination of optimum SR because of the trade-off between the possibility of higher production and the certainty of higher costs.

The aim of the present paper is to examine the effect of various input/output price ratios on the stocking rates that maximize net production value of a supplemented beef herd. An attempt is made to present the case in general terms so as to extend the implications beyond the situation for which the basic data for the exercise were obtained.

Method

The value of the weaned calf liveweight production of the cow is dependent on the local value of the product less the combined costs of supplementary feed, variable non-feed costs, and fixed costs. The variable costs vary with the size of the herd and thus with SR. They include interest on the investment in the cow, bull maintenance, veterinary costs, variable grazing costs, levies, and other costs that vary with the number of cows. The fixed costs include annual cost of pasture, equipment, building structures, maintenance, management, and other costs that do not vary significantly with changes in herd size (Hart 1972). In order to reduce the influence of local prices on the analysis, all money values are expressed as kg of weaned calf liveweight or as price ratios. This is an unnecessary conversion for any specific situation, but has the advantage of generality, especially where nonmonetary estimates of value are common. For instance, labor costs may be difficult to evaluate in money terms in certain pastoralist communities, but the relative value of labor to the locally estimated value of the livestock product should be easier to determine. Similarly, the cost of the supplementary feed can be expressed as a ratio between the cost of the feed, in whatever terms are relevant to the operator, and his estimate of the value of his produce (Quigley et al. 1984). In the present study, we assume a more or less constant overall composition of the supplementary feed so that only the amount will be varied with changing stocking rate and not the quality. In some cases it may be necessary to treat the different supplementary feed components separately.

In a cow/calf herd that is being given supplementary feed during part of the year, the net value of the annual weaned liveweight production per cow, V_c, is:

$$V_c = W(H) - aS(H) - k - j/H \quad (1)$$

where

H = stocking rate per unit area (cows/ha)
W(H) = mean weaned calf liveweight production per cow (mean weight of calves × weaning rate) as a function of H (kg/cow/yr)
S(H) = amount of supplementary feed given per year as a function of H, expressed as metabolizable energy, ME

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(Mcal/cow/yr)

a = ratio between the price of a nutrition unit (ME) of supplementary feed and the price of a unit of liveweight in (\$/Mcal)/(\$/kg), which reduces to kg LW per Mcal of feed (kg/Mcal)

k = non-feed costs per cow in terms of weaned LW (kg/cow/yr)

j = fixed pasture and herd management costs per unit area of range in terms of weaned LW (kg/ha/yr)

Maximum V_c in dependence on SR is attained when $dV_c/dH=0$, so that it depends only on a and j and not on k. This formulation assumes that SR varies with changes in the number of animals on a fixed area of rangeland and that j is independent of stocking rate (H). If the herd size is fixed and SR varies with changes in range area, a different formulation would be necessary. The net value of the measured calf liveweight production per unit area, V_a is:

$$V_a = H.V_c \quad (2)$$

Maximum V_a in dependence on SR, or optimum SR, is attained when $dV_a/dH=0$, so that it is not dependent on j, the fixed pasture and herd management costs but only on a a and k. Both mean weaned calf liveweight production per cow, W, and the amount of supplementary feed, S, necessary to attain W, are dependent on SR. Thus, both W and S need to be expressed as functions of SR (or H). If other elements of the production function are also dependent on H, they can be incorporated into these values. For instance, if the net gain or loss from selling replacement cows and recruiting young pregnant stock is dependent on SR, then it could be included in W (H). If it is a constant value it can be included in k. As data are often inadequate or too irregular to be expressed as simple algebraic expressions, it is convenient to use tabular functions and to interpolate intermediate values (Table 1).

Table 1. Mean 5-year calf weight and supplementary feed energy fed per cow in relation to stocking rate[1].

Stocking rate cows/ha (H)	Weaned calf liveweight kg/cow/yr (W)	Weaned calf liveweight kg/ha/yr (HW)	Supplementary feed (ME) Mcal/cow/yr (S)
0.50	162	81	1697
0.67	145	97	1710
0.83	145	120	2496

[1]Data from experiment conducted at the Karei Deshe Experiment Range, Lower Galilee, Israel (Gutman, Seligman and Noy-Meir, unpublished manuscript).

Where the functions of W and S are available and where all the other parameter values are available, the net value of weaned LW production per cow and per ha can be easily calculated and optimum SR can be determined. However, it is also helpful to know the sensitivity of optimum SR to changes in the values of the different parameters, in particular to changes in a, k, and j. Whereas parameter a can conceivably affect the shape of the net value response surface to H both per cow and per ha, the shape of the response surface of net value per cow would not be affected by k and that of net value per ha would not be affected by j because these are constants in each respective case. Consequently, the sensitivity analysis can be restricted to a and j where per cow responses are concerned and to a and k where per ha responses are concerned.

Animal, forage and supplementary feed data

The data for this analysis were taken from a 5-year set of data from an experiment conducted at the Karei Deshe Experimental Ranch in the lower Galilee of Israel, lat. 32°55'N, long. 35°35'E, alt. 150 m (Gutman, Seligman and Noy-Meir, unpublished manuscript). The vegetation is a herbaceous, hemicryptophytic, Mediterranean batha (Zohary 1973) dominated by *Hordeum bulbosum* L., *Echinops* spp. and *Psoralea bituminosa* L., with many annual forbs and grasses; annual primary production varied between 2,500 and 3,500 kg DM/ha. The cows were commercial crosses and backcrosses between the local Balady landrace and Hereford, Brahman and Simmenthal bulls. The cows were relatively small, weighing between 250 and 450 kg. They were maintained at 3 stocking rates (0.50, 0.67, and 0.83 cows/ha) and grazed yearlong in paddocks 28–33 ha in size. The breeding season was between December and the beginning of May, and calving occurred between September and February. The animals were given sun-dried broiler house litter ad libitum, mainly as a non-protein nitrogen (NPN) supplement (Allden 1981, Holzer and Levy 1976) throughout the dry summer when the protein content of the dry pasture declined from 5.6% in May to 3.1% in September. The average nitrogen content of the poultry litter (PL) was 4% and its estimated metabolizable energy concentration was approximately 1.5 Mcal/kg DM (Holzer et al. 1986). From the beginning of the calving season, cows that were due to calve were given 20% barley grain (BG) mixed with the PL. At the heavier stocking rates, straw (ST) was fed when pasture availability became very low, generally below 500 kg/ha.

Functions and Parameter Estimation

The function tables that were derived from these data (Table 1) were linearly interpolated to construct continuous functions of weaning weight per cow and supplementary feed per cow in relation to SR. The range of appropriate values for the ratio of feed costs to weaned LW price, a, was determined as follows: PL and ST constituted 86 to 88% of the diet, the rest being BG. The local prices are \$40–50/ton for PL or ST; \$150/ton for BG and \$2.2/kg for weaned LW (at 150–250 kg weaning weight). Metabolizable energy (ME) concentration of PL and ST is estimated at 1.5 Mcal/kg DM (Holzer et al. 1986) and that of BG 2.9 Mcal/kg DM (NRC 1984). The price of supplementary feeds is thus \$58.65/ton, or \$34.87/1000 Mcal. Consequently, for a weaned LW price of \$2.20/kg, parameter a = 15.8 kg LW/1000 Mcal; for LW price of \$1.10/kg, a = 31.7 and for 30% cheaper feed costs, with price of LW = \$2.20/kg, a = 11.1. Thus, values from 10 to 30 represent a fairly wide range under local conditions.

The value of the non-feed costs per cow, k, that includes, say 10% interest on the value of the cow that weighs 350 kg and that is worth half the price of weaned LW per kg, would be equivalent to 17.5 kg weaned LW; other variable costs of more or less the same order of magnitude would make k = 35. Hart (1972) quotes figures that give k = 63.5. A range of 20 to 80 kg weaned LW equivalent for k should therefore cover circumstances that occur in many beef herds.

The value for the fixed costs per unit area, j, will depend on the size of the farm, the annual cost of the investment in land and on the efficiency of farm management. As this includes fixed labor costs at, say, 1 man-year per 250 cows it would work out at about 10 kg LW at local prices. Other fixed costs could put the value of j up to 20 kg weaned LW equivalents per ha. A range of values of j from 10 to 30 would therefore cover a wide range of realistic conditions.

Sensitivity Analysis

Using these values, a set of response surfaces that represents the net value of production in terms of weaned calf liveweight per cow, V_c and per hectare, V_a, was constructed. In Figure 1, V_c is presented as a function of SR (or H) and the feed/liveweight price ratio, a, for different values of fixed herd and pasture management costs, j

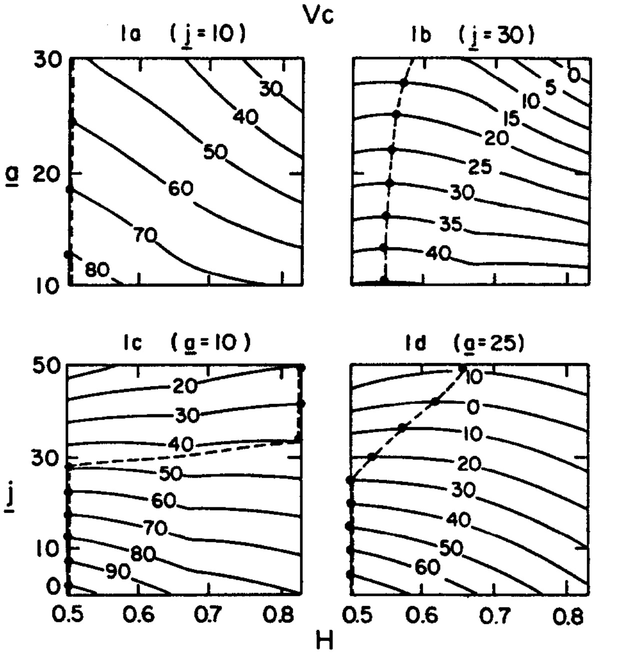

Fig. 1. *Response surfaces of net weaned calf liveweight production per cow, V_c, as a function of stocking rate H, ratio of feed costs to weaned price, a, and fixed herd costs, j.*
1a. Response of V_c to H and a for j = 10; 1b. response of V_c to H and a for j = 30; 1c. Response of V_c to H and j for a = 10; 1d. Response of V_c to H and j for a = 25.
In all cases, variable costs per cow, k= 40, do not influence the shape of the response surface.
•--•Ridge of maximum values in the tested parameter range.

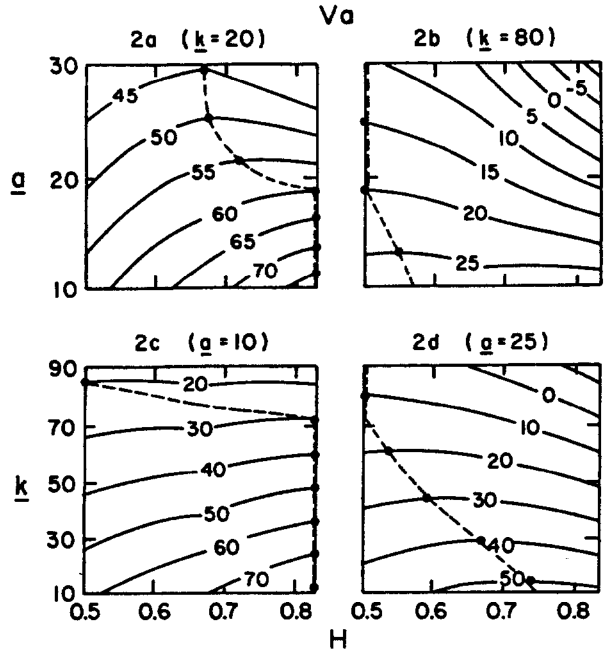

Fig. 2. *Response surfaces of net weaned calf liveweight production per hay, V_a, as a function of stocking rate H, ratio of feed costs to weaned price, a, and fixed herd costs, k.*
2a. Response of V_a to H and a for k = 20; 2b. variable non-feed costs per cow, response of V_a to H and a for k = 80; 2c. Response of V_a to H and k for a = 10; 1d. Response of V_a to H and k for a = 25.
In Figs. 1a and 1b, j = 5; in Figs 1c and d, i = 10. In all cases, j (fixed herd costs) does not influence the shape of the response surface.
•--•Ridge of maximum values in the tested parameter range.

(Figs. 1a, 1b), and as a function of H and *j* for different values of *a* (Figs. 1c, 1d). In Figure 2, V_a is presented as a function of H and *a* for different values of non-fixed costs per cow, *k*, (Figs. 2a, 2b) and as a function of H and *k* for different values of *a* (Figs. 2c, 2d). In all the figures, the maximum values of V_c and V_a for different values *a*, *j*, and *k* are marked with a large dot.

Results and Discussion

Net Value of Weaned Liveweight Production Per Cow

Over a range of realistic SR for the study region (H = 0.5 to 0.83 cows/ha), the maximum return per cow can vary over the whole range of H depending mainly on *j*, the fixed costs per unit area (Figs. 1a–1d). When these are below 30 kg LW per ha, maximum V_c is obtained at low SR (H = 0.5) but as *j* increases above 30 kg LW/ha, V_c shifts towards high SR (H = 0.83) (Fig. 1c). The effect of the feed/liveweight price ratio is small (Figs. 1a, 1b) and only influences the SR for maximum V_c when both fixed costs per unit area, *j*, and the price ratio, *a*, are high (Fig. 1d).

From these results it can be concluded that SR for maximum return per cow need not necessarily be at the low end of a realistic range of stocking rates. Where fixed herd and range management costs per unit area are high in relation to the gross value of the production per cow, economic return per cow is maximized at an intermediate or higher SR. In a sense, this may be regarded as an economically "optimal" SR in situations where return to capital invested in the herd is the decisive consideration of the manager. This is not the usual definition of "optimum SR", which is discussed in the following section.

Net Value of Weaned Liveweight Per Unit Area

When non-feed costs per cow, *k*, are low relative to the value of mean measured calf liveweight, then optimum SR for maximum return per unit area is high (H = 0.83 cows/ha) as long as the price ratio between feed and weaned liveweight, *a*, is also low (Fig. 2a). But as that ratio rises above 20 kg LW/1000 Mcal ME, the optimum SR falls to around H = 0.67 cows/ha. On the other hand, when the non-feed costs per cow, *k*, are high (Fig. 2b), optimum SR is low (H = 0.5) and increases slightly only when the feed/liveweight price ratio, *a*, is well below 20 kg LW/1000 Mcal ME. The sensitivity of optimum SR to fixed costs per cow, *k*, is low when the price ratio, *a* is low and shifts from H = 0.83 to H = 0.5 cows/ha only when *k* is above 80 kg LW/cow (Fig. 2c). In contrast, when the feed/liveweight price ratio, *a*, is high, optimum SR is above H = 0.7 only for low non-feed costs ($k<20$ kg LW/cow) and as these increase, optimum SR falls to H = 0.5 cows/ha (Fig. 2d).

In conclusion, SR that maximizes return per unit area, V_a, can be anywhere in the range of SR that was tested, depending on *a*, the price ratio between supplementary feed and weaned liveweight and on *k*, the non-feed costs per cow. Optimum SR tends to be low when non-feed costs per cow are high. It tends to the high when the price ratio between supplementary feed and weaned liveweight is low. These conclusions assume that, within the range of SR analyzed, range condition is not materially affected by SR or by grazing system. This has been shown to be so in the study area (Gutman, Seligman and Noy-Meir, unpublished manuscript).

Conclusions

The response of net value of weaned calf liveweight per cow and per unit area to increasing SR can be qualitatively different from the simple biological response of weaned liveweight production per cow and per unit area to increasing SR. The interactions with relative cost of supplementary feed and with fixed herd and variable cow costs of the operation are not immediately obvious. Consequently, it is also not generally recognized that over a wide range of viable operating conditions, the net value of LW production per cow can increase with SR even when production per cow decreases, and that the net value of weaned weight per unit area can decline with increasing SR even when production per unit area increases. In any case, it is suggested that response surfaces like those in the present study can help to elucidate the sensitivity of the economic response to stocking rate, particularly when the data base is relatively small.

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