Evaluation of Differing Genetic Potentials on Beef Cattle Resource Use in the Great Plains

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Abstract

Natural resource management is one of the keys to improving the sustainability of the beef industry. The objective of this project was to simulate 444 various cow-calf operations with differences in genetic potential, regional feedstuff availability, and climate to contrast land and water requirements, as well as methane emissions. The simulations replicated 74 different land regions in the Great Plains and six varying genetic potentials for cow mature size (large, moderate, and small) and milk production (high and low) within those regions. Weaning weight was also estimated to calculate the natural resource efficiency of each genetic potential.

Animals with greater energy demands (larger mature weight and/or higher lactation potential) required more natural resources. For example, heavier animals required more grazing land than lighter animals and emitted more methane per year. Interestingly, lactation potential influenced water requirements more than body size. High lactation animals had a larger irrigation footprint than low lactation animals of the same size as the high lactation animals required more supplementation (usually a hay and/or grain ration). This was because the model parameters prevented the animals from consuming more than 2.7% of their body weight in feed per day and high lactation animals could not meet their energy needs through forage alone. When natural resource use was scaled by estimated pounds of weaned calf produced, smaller animals were more efficient than larger animals. Small, high lactation cattle required the least total land and emitted the fewest pounds of methane per pound of weaned calf; while small, low lactation animals were the most efficient users of water.

Introduction

Sustainability in beef production has recently received a great deal of attention. In particular, environmental sustainability has received the most scrutiny from the public. The most discussed aspect of environmental sustainability is the greenhouse gas (GHG) footprint of the beef industry; however, environmental sustainability also encompasses land and water resources used in beef production.

Properly accounting for the environmental impact of beef cattle in the U.S. is a difficult task. This is partly because the resources used and the GHGs emitted are difficult to track and accurately measure. Further compounding the problem is the large scale of the U.S. beef industry and the variety of management and climatic conditions. Thus, one of the most robust and effective methods available to the scientific community to investigate the beef industry's environmental footprint is simulation. Simulation also allows for mitigation assessment, by comparing how changing one or a few factors affects sustainability metrics. In this study, mature cow body size and pounds of milk produced at peak lactation were altered to examine the impact genetic potentials have on natural resource use while still accounting for regional differences in production practices.

Experimental Procedures

A stochastic simulation model was utilized to simulate a 100-head cow-calf operation over a 25-year period (Aherin, 2020). The program simulated six herds with differing combinations of genetic potential within 74 land use regions in the Great Plains resulting in 444 unique scenarios. Body size (large, moderate, and small) was parameterized for each herd using data from regional surveys of cattle producers (Asem-Hiablie et al., 2015; Asem-Hiablie et al., 2016). Low lactation potential was designated 17.6 lb milk per day at peak lactation while high lactation potential was 24.2 lb milk per day at peak lactation (NRC, 2016). Cattle were assumed to be grazing from May 1 to October 31 with supplement fed per cow as needed to maintain a body condition score of 5. Stocking rate for each scenario was based on observed stocking rates and scaled to match mature body weight (BW; Asem-Hiablie et al., 2015; Asem-Hiablie et al., 2016). From November 1 to April 30, the cattle were assumed to have received enough ration of hay and grain to maintain a body condition score of 5. Supplemental and delivered rations were formulated to be representative of common feedstuffs in each region.

Average yield for each feedstuff was found for a representative county located in each land region. The as-fed weight of the feedstuffs was divided by the yield of the feedstuff in that region to calculate the acres of land required to grow feedstuffs. For by-product feedstuffs, land and water used to grow the original crop was scaled by the percent mass of the by-product compared to the mass of the original crop. Grazing land was found by multiplying the number of animals of each class (replacement heifers, bred heifers, and mature cows) by the stocking rate of each class. Total land was the sum of land required to grow feedstuffs and grazing land.

Irrigation water needs were found by subtracting rainfall measurements from average crop water needs as determined by the Blaney-Criddle method (Blaney and Criddle, 1950; Brouwer and Heibloem, 1986). Total irrigation water was found by multiplying irrigation needs by the area of crop land allocated to growing feedstuffs. Drinking water was estimated for the herd each month by adjusting a baseline water intake by BW, peak lactation, and monthly temperature in each scenario and multiplying by the number of cattle in the herd (Spencer et al., 2017). Total water use was calculated as the sum of irrigation water and drinking water.

The gross energy of each diet was multiplied by dry matter intake of each diet. The gross energy intake was inserted into the IPCC Tier 2 methane estimation model to find the pounds of methane produced in each scenario in the average year (IPCC, 2019).

Weaning weight was estimated by taking the national average weaning weight of all calves from herds with 50–199 head (roughly 542 lb; USDA, 2020), and adding/subtracting 0.1476 lb in weaning weight for every 1 lb increase/decrease from 1208 lb in maternal weight (Ziegler, 2020). Weaning weight was then adjusted for milking potential by adding/subtracting 6.6 lb of weaned calf for every 1 lb increase/decrease from 22 lb of milk per day at peak lactation (King et al., 2020; Fraga et al., 2013).

Results and Discussion

Large animals required more total land than small animals regardless of lactation potential primarily because large animals were allocated more grazing land (Table 1). Grazing land comprised anywhere from 70–98% of the total land required. High lactation animals required the most supplement. This was because the model parameters prevented the animals from consuming more than 2.7% of their BW in feed per day, and high lactation animals could not meet their energy needs through forage alone.

Total water required was driven more by lactation potential than mature weight (Table 1). Animals with high milk yields required more total water than animals with low milk yields because of the additional need for crop land and the fact irrigation comprised between 75–99% of the total water required. Within lactation potential, large animals required more total water than smaller animals. In terms of drinking water, large animals drank more than small animals, and animals that produced greater amounts of milk drank more than low milking animals of the same size.

Methane production in this study was primarily driven by feed intake (Table 1). Animals with greater feed intake generally have greater methane emissions. Therefore, larger cattle produced more methane than smaller cattle. Higher milking cattle also produced more methane than lower milking cattle of the same weight.

When environmental footprint was scaled by weaning weight, it was shown that small, high milking cattle were the most efficient users of grazing land, total land, drinking water, and produced the least methane per pound of weaned calf (Table 2). In addition, small, low milking animals used the least crop land and irrigation water per pound of weaned calf. Conversely, large animals with low lactation potential generally had the greatest environmental impact per pound of calf weaned.

Although the results are a summary of average trends across the Great Plains, the genetic potential that is the most efficient on average may not be the genetic potential that is the most efficient in every location because weaning weights of different genetic potentials may vary from region to region. Further, environmental sustainability needs to be balanced with social and economic considerations.

Implications

Animals with greater energy requirements have larger environmental footprints. However, small, high lactation cattle required the least total land and emitted the fewest pounds of methane per pound of weaned calf, while small, low lactation animals were the most efficient users of water.

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Table 1. Average annual environmental impact of a 100 head cow-calf herd with differing genetic potentials in the Great Plains

Genetic potential[1]	Grazing land (ac)	Crop land (ac)	Total land (ac)	Drinking water (1000 gal)	Irrigation water (1000 gal)	Total water (1000 gal)	Methane (tons)
Large weight							
High milk	1757	156	1913	462	8299	8761	10.49
Low milk	1757	141	1898	446	7601	8047	10.17
Moderate weight							
High milk	1613	151	1764	443	7998	8441	10.00
Low milk	1613	137	1750	427	7294	7721	9.61
Small weight							
High milk	1472	146	1618	424	7680	8104	9.48
Low milk	1472	132	1604	408	7001	7409	9.06

[1]Weight (large, moderate, and small) was parameterized for each herd using data from regional surveys of cattle producers. Low lactation potential was designated 17.6 lb milk/day at peak lactation; high lactation potential was 24.2 lb milk/day at peak lactation.

Table 2. Average annual environmental impact per pound of weaning weight (WW) of a 100 head cow-calf herd with differing genetic potentials in the Great Plains

Genetic potential[1]	Grazing land (ac/lb WW)	Crop land (ac/lb WW)	Total land (ac/lb WW)	Drinking water (1000 gal/lb WW)	Irrigation water (1000 gal/lb WW)	Total water (1000 gal/lb WW)	Methane (lb/lb WW)
Large weight							
High milk	0.0252	0.0022	0.0275	0.0066	0.1192	0.1258	0.3013
Low milk	0.0269	0.0022	0.0291	0.0068	0.1165	0.1233	0.3117
Moderate weight							
High milk	0.0237	0.0022	0.0259	0.0065	0.1175	0.124	0.2939
Low milk	0.0253	0.0022	0.0275	0.0067	0.1145	0.1212	0.3017
Small weight							
High milk	0.0221	0.0022	0.0243	0.0064	0.1155	0.1219	0.2851
Low milk	0.0237	0.0021	0.0258	0.0066	0.1127	0.1193	0.2917

[1]Weight (large, moderate, and small) was parameterized for each herd using data from regional surveys of cattle producers. Low lactation potential was designated 17.6 lb milk/day at peak lactation; high lactation potential was 24.2 lb milk/day at peak lactation.