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Role of Ruminant Livestock in Sustainable Agricultural Systems[1]

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ABSTRACT: Ruminants have served and will continue to serve a valuable role in sustainable agricultural systems. They are particularly useful in converting vast renewable resources from rangeland, pasture, and crop residues or other by-products into food edible for humans. With ruminants, land that is too poor or too erodable to cultivate becomes productive. Also, nutrients in by-products are utilized and do not become a waste-disposal problem. The need to maintain ruminants to utilize these humanly inedible foodstuffs and convert them into high-quality foods for human consumption has been a characteristic of advanced societies for several thousand years. Further, ruminant livestock production is entirely consistent with proper agronomy practices in which forages are grown on 25% of arable land to minimize water and soil erosion. Questions have been asked, however, about the use of humanly edible foodstuffs (grains, protein sources, etc.) in ruminant diets. Does their use create a net loss of nutrients for human consumption? What level of their use is necessary or desirable? Does the use of some of these improve the nutrient (e.g. protein) quality or product value? Too often the opponents of animal agriculture evaluate the desirability of animal production on gross calorie or protein intake/output values. However, in many cases the feeds used in animal production are not consumable by humans, and in order to properly evaluate animal production, humanly consumable energy and protein intake should be used for efficiency comparisons. Analysis of the costs/returns of humanly edible energy and protein for a variety of dairy and beef cattle production systems shows that food value is increased with ruminant products, and that net returns of humanly edible nutrients are dependent on the production system used. The efficiency with which ruminants convert humanly edible energy and protein into meat or milk is highly dependent on diet, and hence, on regional production practices. Previous studies suggest that in the United States, dairy production efficiency ranges from 96 to 276% on a humanly consumable protein basis. Beef production efficiency is very dependent on the time spent in the feedlot and digestible energy and protein efficiencies range from 28 to 59% and 52 to 104%, respectively. However, beef production can add to the humanly consumable protein pool depending on the feeding schedule. In addition, the protein resulting from ruminant livestock production is of higher quality with a greater biological value than protein in the substrate feeds. The evidence that ruminant livestock belong in sustainable livestock production systems is convincing.

Key Words: Sustainable Agriculture, Ruminants, Nutrient Use

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Introduction

Ruminants serve a valuable role in sustainable agricultural systems. The rumen serves as a vat containing the microbial enzyme cellulase, the only enzyme to digest the most abundant plant product, cellulose (CAST, 1975). Cattle, sheep, and goats are particularly useful in converting vast renewable resources from rangeland, pasture, and crop residues or other by-products into food. With ruminants, land that is too poor or too erodable to cultivate becomes productive. Also, nutrients in by-products are utilized and do not become a waste-disposal problem.

Some question the use of cereals for animal production. About one-sixth of the energy required by livestock is derived from grains. Poultry and swine consume about 59% of these cereals to produce about 39% of the human food energy from livestock, and ruminants (dairy and beef cattle, sheep and goats) consume about 37% of grains fed to livestock yet produce 61% of human food energy from animal agriculture (Wheeler et al., 1981). Most, if not all, available analyses are not comprehensive and quantitative, thus many conflicting conclusions have been made regarding appropriate resource allocations to

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ruminant agriculture. The real challenge is quantitative consideration of the many interactions between production system and resource use. Economic constraints, alternate cropping, feeding and management systems, and biological limits to productive efficiency must be considered. Optimal integration of crop and animal agriculture must be based on rigorously derived and quantitatively defensible data and analyses (Baldwin et al., 1992).

Sustainability of Land and the Production Enterprise

Non-cereal resources for ruminant feed are enormous. Constituting 55% of the world's land, these pastures, rangelands, meadows, forests, and woodlands have the potential of producing 5.8 trillion Mcal of metabolizable energy annually. Crop residues from other lands contribute up to 2.9 trillion Mcal, and processing by-products about .6 trillion Mcal (Wheeler et al., 1981). In the United States alone, 250 billion Mcal of crop residues and by-products result from crop agriculture. This, if fully converted in today's production systems, could yield 4.5 billion kg of beef or 750 billion kg milk (Smith, 1980). For comparison, U.S. beef consumption is about 5 billion kg.

Ruminant livestock production takes advantage of forage production on approximately 25% of potentially arable land to minimize water and soil erosion. Vast hilly or mountainous areas discourage cultivation and crops (CAST, 1982). Highly erodable land may have no other sustainable economic use than for grazing ruminant livestock. Sod-forming forages protect the soil from erosion. If soil is the focal point for sustainability (Hauptli et al., 1990), then minimization of erosion, compaction, and oxidation also helps maintain its organic state. This is better achieved on any soil by keeping some type of continuous cover as much of the year as possible (Ely, 1994). In arid areas, pastoral use of ruminants in agriculture is utilized, as opposed to the integrated crop and livestock system in more humid areas.

Livestock are essential for family farm agriculture. Glimp (1984) described an integrated, diversified Kentucky farm whereby ruminants (sheep) made the system economically viable and improved the resource base and natural environment. Crop and livestock together make sustainable practices such as crop rotations and production of legume or grass forages possible. Ruminants convert low-quality feeds from land not suited for cultivation into a salable product for farmers and high-quality food for people. Including livestock on the farm also improves living standards on family farms, providing more employment opportunities in rural areas.

It is not always true, as implied by Waggoner (CAST, 1994), that cropland used for animal feed production could produce as many or more calories and protein as when that cropland is used to produce human food crops. For example, in California, alfalfa yields average 15 t/ha annually whereas wheat averages 5.4 t/ha (CDFA, 1993). Alfalfa is about 20% protein; wheat is about 12% protein. Hence, a hectare yields 3,010 kg of protein from alfalfa, or 647 kg of protein from wheat (21.5% that of alfalfa). Dairy cows convert the protein in alfalfa to milk protein at about 25% efficiency, giving 753 kg of food protein per hectare, compared to 647 kg for wheat. In addition, milk and milk protein is of much higher quality and biological value. The wheat crop will take less water but will require considerable nitrogen fertilizer for the yield assumed, whereas alfalfa requires no nitrogen fertilizer (note the groundwater quality implications). Alfalfa adds nitrogen to the soil, which is used by wheat in normal crop rotation. Wheat produces vast amounts of straw, a crop residue, which can also be converted to human food by ruminants as part of the production system.

Competition with Humans for Food

Cereal grains are not necessary for ruminant production, and ruminants need not compete for human foods, although in those systems in which they do not, productivity and efficiency are decreased. Feed grains and other concentrate feeds increase productivity and efficiency, resulting in economical production and maximal use of the forage resource. There are a wide range of strategies in which various proportions of noncompetitive feed resources, grains, and other concentrates can be used for ruminants. Each of these strategies has a different efficiency. A common error is to assign a single efficiency to all types of ruminant meat production.

Questions have been asked, however, about the use of humanly edible foodstuffs (grains, protein sources, etc.) in ruminant diets. Does this use create a net loss of nutrients for human consumption? What level of use is necessary or desirable? Does the use of some of these improve the nutrient (e.g. protein) quality or product value? Too often the opponents of animal agriculture evaluate the desirability of animal production on gross caloric efficiency or protein intake/output values. However, in many cases the feeds used in animal production are not humanly consumable, and in order to determine the true efficiency of animal production, humanly consumable energy and protein intake should be used for efficiency comparisons.

Estimates of returns on humanly edible inputs are shown in Table 1, based on Bywater and Baldwin (1980) but updated to the present (Baldwin et al., 1992). The dairy cow considered in the calculation had an average weight of 636 kg and produced 8,601 kg of 3.5% fat milk in 305 d. Thus, humanly edible outputs of digestible energy (**DE**) and digestible protein (**DP**) were (8,601 kg milk $\times$ .688 Mcal DE/kg

Table 1. Humanly edible returns from cattle production[a]

Production system	Digestible energy	Digestible protein
Dairy I	128	276
Dairy II	57	96
Beef		
Colorado	37	65
Iowa	28	52
Texas	59	104

[a]See text for explanation of systems and bases for estimates.

milk) 5,917 Mcal and (8,601 kg milk × .0298 kg DP/kg milk) 256.3 kg, respectively. Two feeding strategies were considered (Table 2): a least cost ration formulated for California based on common feeds and current practices (Dairy I); and a ration formulated based on alfalfa, corn silage, corn, and soybean oil meal (Dairy II). Both rations contained 1.56 Mcal NE_l/kg and 2.9 Mcal DE/kg. Based on NRC (1989), the average NE_l requirement of the cow would be 29.5 Mcal/d, daily feed intake would be (29.5 Mcal/d ÷ 1.56 Mcal/kg) 18.9 kg/d, and total feed intake during lactation would be 5,765 kg, or 16,717 Mcal of DE. Further considerations in estimating returns from dairy production are given by Baldwin et al. (1992).

A highly conservative assumption used is that all corn that is ensiled could mature in the field until edible corn constitutes 45% of dry matter. With this consideration, humanly edible inputs during lactation (Dairy I) would be 4,460 Mcal:

Barley (.093 × 2.9 × 5765)	1,555 Mcal
Corn silage (.35 × .45 × 3.2 × 5765)	2,905 Mcal
Sum	4,460 Mcal

Humanly edible returns during lactation would be (5,917/4,460) 133%. In areas where frosts occur early, such that shelled corn cannot be produced or where corn silage is produced as a component of a double-cropping strategy, this assumption causes underestimation of humanly edible returns because of the biased (high) value of humanly edible energy from corn silage. In fact, during lactation, if one assumes that only the grain at ensiling (late milk stage, 16% of DM) is humanly edible, the humanly edible return is 230%; if one assumes that corn silage is humanly inedible, the return is 380%.

Thus, the returns on humanly edible inputs to a California dairy enterprise are (using the most conservative assumption):

Energy inputs (Mcal DE):	
Lactation	4,460
Dry cows	119
Replacements	224
Sum	4,803
Energy outputs (Mcal DE):	
Milk	5,917
Cull cows	235
Sum	6,152
Return (Human DE):	
Output/input × 100	128%
Human digestible protein inputs (kg):	
Lactation	
Corn silage	49.0
Barley	40.2
Dry cows	3.3
Replacements	5.3
Sum	97.8
Human digestible protein outputs (kg):	
Milk	256.3
Cull cows	13.1
Sum	269.4
Return (Human DP):	
Output/input × 100	275%

Similar calculations were used to estimate returns on humanly edible inputs to a corn/soy-based enterprise (Dairy II).

The two scenarios presented for dairy production systems are conservative and the estimates minimal. Similarly, the two scenarios, Dairy I and Dairy II, represent extremes. The diet used for Dairy I is heavily based on by-products and other feedstuffs not consumed by humans and, thus, approaches maximum estimates of humanly edible returns from dairy production (Baldwin et al., 1992). Dairy II incorporates no by-products, so its humanly edible returns are minimal.

A model of beef production (Beckett and Oltjen, 1993) with feed inputs in Colorado, Iowa, and Texas was used to estimate humanly edible inputs for beef production. These states were chosen due to differences in beef production strategies. California was not chosen because the estimates in Table 1 apply to beef production from beef breeds of cattle but total inputs for beef production in California are confounded by the large number of dairy cows and steers for beef production in the state. Colorado was selected because humanly edible inputs to the cow-calf element are

Table 2. Dairy rations used to estimate human edible inputs during lactation in dairy cows (Baldwin et al., 1992)[a]

Feedstuff	Dairy I	Dairy II
Corn silage	35.2	20.0
Alfalfa hay	33.8	30.0
Barley	9.3	—
Corn	—	37.0
Cottonseed, w/lint	9.3	—
Wheat mill run	7.7	—
Cottonseed meal	4.4	—
Soybean oil meal	—	10.0
Salt, etc.	.3	3.0

[a]Values expressed as percent of diet DM.

small and there is heavy use of corn and wheat in the feeder cattle element (over 70% of DM fed). Iowa was selected because corn silage is used in cow-calf operations and high-cereal plus corn silage diets are used in the feeder phase. Finally, Texas was selected because it is a major beef-producing state in which cattle entering the feedlot are heavier and, thus, fed for a shorter period. The range of returns varies considerably (Table 1). Iowa's returns on humanly edible inputs represent an extreme low because of a high use of corn and corn silage. Colorado is intermediate. Texas estimates represent a shorter feeding period. The return values are conservative (minimal), as with the dairy ones; they can be increased by more moderate assumptions.

Summary and Conclusions

Animal agriculture is an integral part of food production systems, using lands and products not usable by humans for the production of human food, making useful contributions to crop rotations and soil conservation through the growing of forages, serving as a buffer for feed grain supplies and prices, and improving nutritional quality of the diet, as well as adding variety and palatability. It can be argued that the best way to improve agricultural sustainability is to improve forage yields and characteristics.

The use of cereal grains in ruminant production improves efficiency and productivity. Their use is currently essential to the economic production from our pasture, range, crop residue, and by-product resources. Analysis of the costs/returns of humanly edible energy and protein for a variety of dairy and beef cattle production systems shows that net returns of humanly edible nutrients are dependent on the production system used. The efficiency with which ruminants convert humanly edible energy and protein into meat or milk is highly dependent on diet, and hence, on regional production practices. Previous studies suggest that in the United States, dairy production efficiency ranges from 96 to 276% on a humanly consumable protein basis. Beef production efficiency is very dependent on the time spent in the feedlot and digestible energy and protein efficiencies range from 28 to 59% and 52 to 104%, respectively. However, beef production can add to the humanly consumable protein pool depending on the feeding schedule. In addition, the protein resulting from ruminant livestock production is of higher quality with a greater biological value than protein in the substrate feeds.

Most careful analyses conclude that if food requirements of the expanding world population are to be met, both in terms of quantity and quality, all available food production resources must be used effectively and efficiently. Ruminants are integral in those systems and as sources of human food.

Implications

Ruminants will continue to serve a valuable role in sustainable agricultural systems. They are particularly useful in converting vast renewable resources from rangeland, pasture, and crop residues or other by-products into humanly edible food. With ruminants, land that is too poor or too erodable to cultivate becomes productive. Also, nutrients in by-products are utilized and do not become a waste-disposal problem. The need to maintain ruminants to utilize these humanly inedible feeds and convert them into high-quality foods has been a characteristic of advanced societies for several thousand years. The evidence that ruminant livestock belong in sustainable livestock production systems is convincing.

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