

The Carbon Footprint of Beef Production

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INTRODUCTION

Modern-day agriculture allows the average farmer to produce enough food to feed 125 other people. This is in sharp contrast to the historical agricultural systems exemplified by farming in the 1800s, when each farm could produce only enough food to feed one other family. The global population has increased in line with productivity, yet the rate of increase in meat consumption is greater than the population increase, as previously impoverished regions make economic gains. By the year 2050, the global population is predicted to increase to approximately 9.5 billion people. This will increase total food requirements by 70% compared with the present day (Food and Agriculture Organization of the United Nations, 2009) as a function of population size and the augmented demand for milk and meat protein resulting from greater global affluence. Assuming that present competition between agricultural, industrial, and urban communities for energy, land, and water continues, global livestock industries will face the challenge of producing a sufficient amount of food from animal sources to meet consumer demand, using a finite resource base. It is therefore crucial to adopt technologies and management practices that maximize productive efficiency (food output per unit of resource input) to reduce the environmental impact of food production and to demonstrate the commitment of the agricultural industry to sustainability.

The phenomenon of climate change is a relatively recent one, yet it has led to considerable consumer concern regarding meat production and food choices. Print, television, and social media include references to the "carbon footprint," "sustainability," and "local food" and there is growing interest in understanding where food comes from. The popularity of "meatless Monday" schemes within restaurants, schools, and workplaces provides evidence of consumers' desires to mitigate their environmental impact through lifestyle changes. Unfortunately, the environmental effects conferred by neglecting to eat meat for 1 d per week have been

hopelessly overpromoted within the media. In a country where less than 2% of people are employed within agriculture, consumers appear to believe that reducing meat intakes can have a significant effect on climate change. The environmental impact of livestock production looms like a specter over current food discussions, with myriad "authorities" (ranging from the media and celebrities to pseudolegitimate activist groups) advising consumers that a vegetarian or vegan lifestyle is the best choice for the environmentally conscious consumer. The oft-debated finding of the Food and Agriculture Organization (2006) that livestock production contributes 18% of total global greenhouse gases (**GHG**) is often used to support this statement, despite the fact that nationally, livestock production contributes only 3.4% of US GHG emissions (US Environmental Protection Agency, 2010). Despite pressure from the anti-animal-agriculture contingent, according to a 2009 poll, only 3% of US adults are vegetarian (<http://www.vrg.org/press/2009poll.htm>). It therefore appears that most consumers do not wish to give up the high-quality protein provided by meat products. Nonetheless, a preponderance of self-proclaimed experts with no background in food production (Pollan, 2007; Walsh, 2009) advocate low-input, extensive systems as being more environmentally sustainable than conventional, intensive production systems.

IMPROVING PRODUCTIVITY HAS REDUCED THE ENVIRONMENTAL IMPACT OF THE US BEEF INDUSTRY

Improving productivity plays a key role in reducing the environmental impact of livestock production. If meat yield or growth rate can be increased, fewer resources are required to produce the same amount of food (Capper, 2010a, b). For example, beef carcass yield per animal has increased over the past 30 yr from 274 kg in 1977 to 351 kg in 2007 (US Department of Agriculture, 1978; US Department of Agriculture/National Agricultural Statistics Service, 2008), which, in combination with reduced time to slaughter over the same time period (606 d vs. 482 d), reduces resource use per unit of meat (Capper, 2010a). The reduction in the environmental impact of livestock conferred by an improvement in productivity efficiency is achieved through the "dilution of maintenance" effect (Capper et al., 2009). All animals have a maintenance nutrient requirement that must be fulfilled each day to

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support vital functions and minimum activities; this may be considered the fixed cost of livestock production. Improving productivity, such that a greater amount of milk or meat is produced in a set period of time per unit of animal input, reduces the total maintenance cost per unit of food produced. Within the beef industry, a population-wide reduction and dilution of maintenance occurs, which encompasses the effects of and interaction between meat yield per animal, the daily population maintenance requirement, and the time period from birth to slaughter. Total beef production was increased in 2007 (11.9 billion kg) compared with 1977 (10.6 billion kg), yet it is noticeable that the slaughter population was reduced by 825×10^3 animals per billion kilograms of beef over the same time period. A concurrent decrease in the size of the supporting population reduced the total maintenance requirement (Capper, 2010a). Because maintenance nutrients may be considered a proxy for resource use (feed, land, water, fossil fuels) and waste output (manure, GHG), a reduction in population maintenance reduces the use of resources per unit of beef produced.

Advances in management, genetic selection, ration formulation, and growth-enhancing technologies between 1977 and 2007 were the main drivers of the productivity gains, with an increase in growth rate reducing the total days from birth to slaughter. Between 1977 and 2007, the average age at slaughter declined from 606 to 482 d. In combination with increased beef yield per animal, reducing the size of the supporting population producing a set quantity of beef in 2007 required 70% of the animals, 81% of the feed, 88% of the water, and 67% of the land needed by the 1977 system (Figure 1). Along with the changes in resource use, improved productivity meant that manure and GHG emissions were considerably reduced, with a 16% decrease in the carbon footprint per unit of beef (Capper, 2010a).

THE MYTH OF EXTENSIVE SUSTAINABILITY

Improving productivity compared with the extensive systems of yesteryear is a relatively easy way to mitigate the environmental impact of beef production. As the industry moves toward the future, a far bigger challenge awaits. Singer and Mason (2006) coined the phrase "ethical consumerism" to describe the growing interest in the way in which food is produced and the practices used, and a concern for low environmental impact, high animal welfare, and optimal worker conditions. Nonetheless, without due consumer education, popular perceptions of sustainable agriculture are often directed toward extensive systems, organic production, or farms that supply only the local geographic area. Although it is widely understood that improving efficiency reduces expense, resources, and waste, the consumer often appears to consider efficiency to have negative connotations when applied to food production. Survey data indicate that consumers desire food products that are affordable, are animal welfare friendly, and have a low environmental impact (Croney, 2011), yet the popular view is that affordability is mutually incompatible with either of the latter factors. Media coverage of "cheap" food, which suggests that extensive systems are superior to conventional beef production in terms of nutritional quality, GHG emissions, and animal welfare, further serves to propagate this idea (Walsh, 2009). Given that products labeled "organic," "natural," or "hormone free" are supplied at a greater economic cost (Yiridoe et al., 2005), the subliminal impression conveyed is that conventional production must occur at the expense of environmental, animal, or human health. In the report *Livestock's Long Shadow*, the Food and Agriculture Organization of the United Nations (2006) concluded that it is essential to continue to intensify livestock production to maintain environmental sustainability. By contrast, consumers often assume that extensive pasture-based

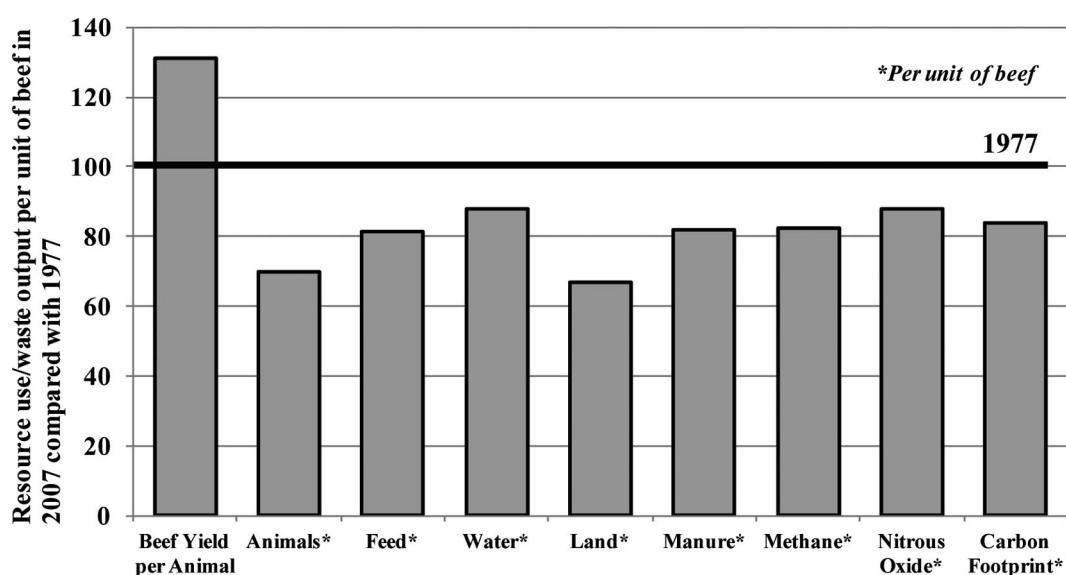


Figure 1. The environmental impact of US beef production in 1977 and 2007 (Capper, 2010a).

beef systems, in which cattle are finished on grass, have a lower carbon footprint than conventional corn-based systems.

The majority of the life of a conventionally reared beef animal is spent on pasture, with feed crop inputs and by-products (corn, soybeans, distillers grains) playing a significant role during the finishing period. By contrast, certified grass-fed beef animals are fed forage throughout their lifetime. If we take a superficial view, considering only the energy inputs required to produce and harvest corn in conventional systems compared with the animals “harvesting” the pasture through grazing, the suggestion that grass-fed beef has a lower environmental impact appears to be supported. However, this suggestion relies on three erroneous assumptions, namely, that 1) animals within both systems finish at the same slaughter weight and carcass quality; 2) slaughter weight is reached in the same time period within both systems; and 3) diet composition has no effect on daily GHG production via enteric fermentation.

Pelletier et al. (2010) reported that GHG emissions per kilogram of beef were greater in pasture-finished systems compared with feedlots. This result seems intuitively incorrect—a conventional system that finishes animals on corn-based diets grown with significant fertilizer inputs that transports both feed and animals across the United States and houses animals in confinement would appear to have an intrinsically higher environmental impact than a grass-finishing system. However, from a biological viewpoint, the results are entirely logical. Growth rates are considerably lower in animals finished on grass and it is difficult to achieve high slaughter weights; therefore, grass-finished cattle are usually slaughtered at around 486 kg at 679 d of age, compared with 569 kg at 453 d of age

in a conventional system (Capper, 2010b). Furthermore, GHG emissions from animals fed high-forage diets are considerably higher than those on high-concentrate diets (Johnson and Johnson, 1995). Capper (2010b) assessed the environmental impact of three beef production systems: conventional, natural, and grass-fed. The conventional system consisted of a cow-calf system on pasture, after which 84% of weaned calves entered a stocker/backgrounder system before moving to a feedlot at 12 mo of age. The remaining 16% of weaned calves entered the feedlot at 7 mo of age. 12.5% of animals within the feedlot entered as surplus calves from the dairy industry. Technologies that improve productivity (ionophores, implants, in-feed hormones, and b-agonists) were used where appropriate according to label instructions within all subsystems of the conventional beef system. Animals were finished at a mean live weight of 569 kg after an average of 453 d from birth to slaughter. The natural system was identical to the conventional system, except that no productivity-enhancing technologies were used. Animals in the natural system were slaughtered at 512 kg after an average of 464 d from birth to slaughter. Within the grass-fed system, animals were fed a 100% forage-based diet as prescribed by the USDA Agricultural Marketing Service standard (2007). Average slaughter weight in the grass-fed system was 486 kg at 679 d of age.

As a consequence of the reduced slaughter weight, 4.5 total animals (slaughtered animals plus the supporting population required to produce calves for rearing) were required to produce 363 kg of hot-carcass-weight beef in a grass-finished system compared with 2.6 total animals in a conventional system. When combined with the increased time required to raise animals to slaughter weight, this increased the carbon footprint per kilogram

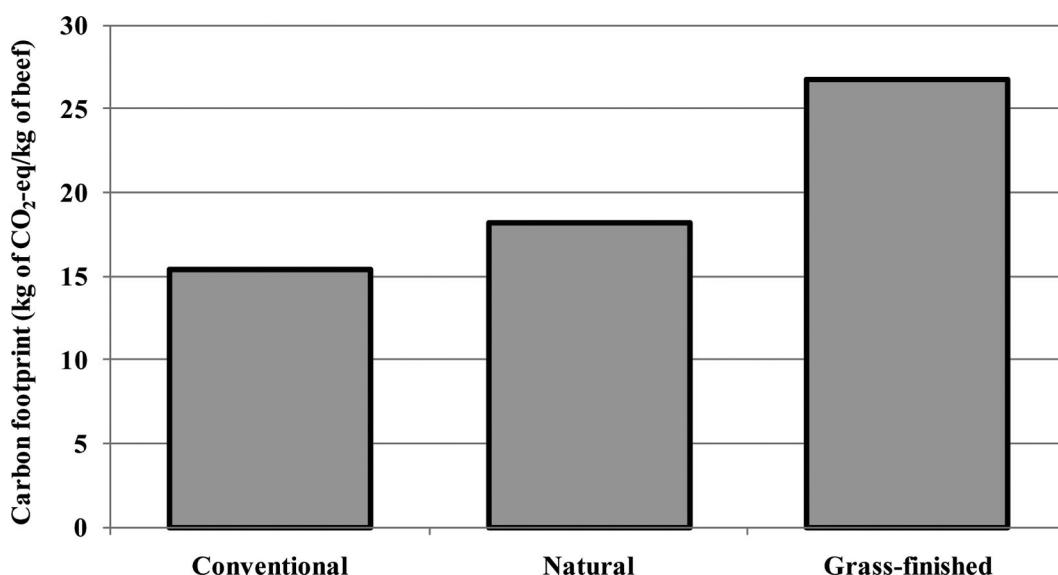


Figure 2. The comparative carbon footprint of conventional, natural, and grass-fed beef (Capper, 2010b). Adapted from Capper (2010b). Carbon footprints based on full-system analyses with full productivity-enhancing technology use (conventional) and feedlot finishing; no productivity-enhancing technology use plus feedlot finishing (natural); or no productivity-enhancing technology use plus grass finishing (grass-finished). eq = equivalent.

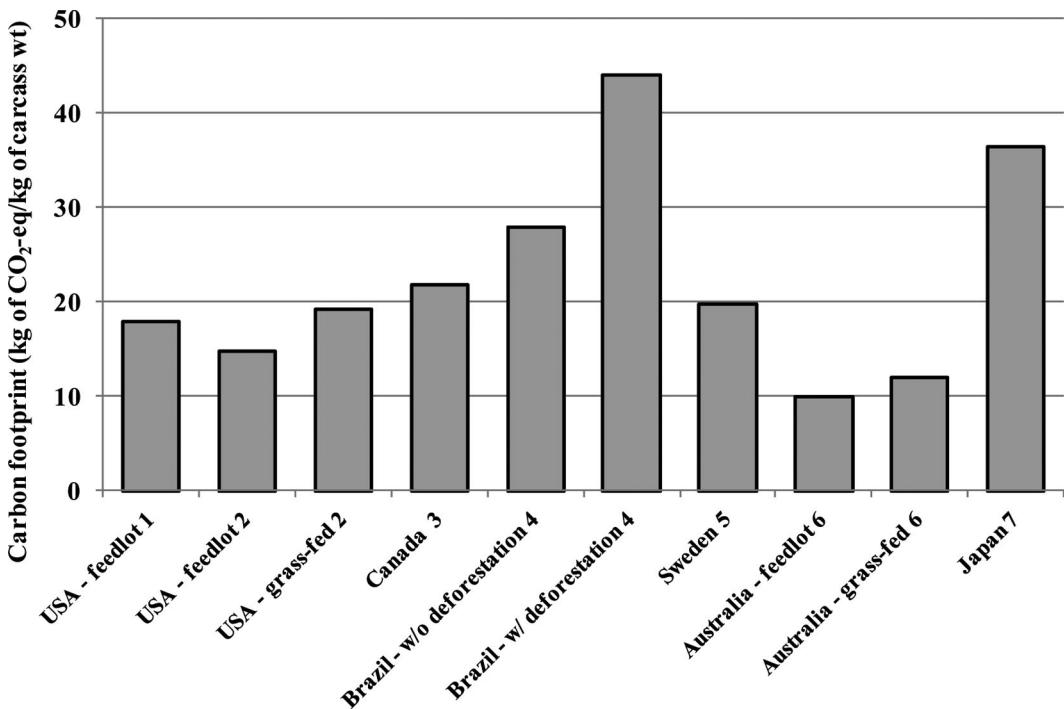


Figure 3. Carbon footprints of regional beef production systems. 1: Capper (2010a); 2: Pelletier et al. (2010); 3: Beuchemin et al. (2010); 4: Cederberg et al. (2010); 5: Cederberg et al. (2009); 6: Peters et al. (2010); 7: Ogino et al. (2004). eq = equivalent; w/o = without; w/ = with

of grass-finished beef by 74% (Figure 2). The quantity of land required for grass-finished production renders whole-scale conversion of the US beef production system to grass-finished production practically impossible. An additional 1.63 ha of land would be required to produce 363 kg of beef in a grass-fed system, increasing the land requirement compared with conventional production by 84%. If we assume that land availability is infinite and that beef production is maintained at 11.8 billion kg, as seen in 2009 (US Department of Agriculture/National Agricultural Statistics Service, 2010), it is interesting to note that the increase in carbon emissions conferred by whole-scale conversion to grass-fed beef production would be equal to adding 26,465,074 cars to the road on an annual basis. Advocates for grass-fed beef systems might argue that although decreased productivity increases GHG emissions from animal sources, the quantity of carbon sequestered by pasture-based systems compensates for reduced efficiencies (International Trade Centre United Nations Conference on Trade and Development/World Trade Organization, Research Institute of Organic Agriculture, 2007). Reliable carbon sequestration data are notably lacking from the environmental literature, and this is one area in which future research would pay dividends in terms of improving knowledge and understanding.

THE VALUE OF COMPARATIVE STUDIES

Many industries appear to be seeking the ultimate answer—the definitive value for the carbon footprint of a specific product. Although a number is required to

benchmark future improvements against current systems, it is my view that comparative studies that provide insight into the relative impact of systems or production practices, and thus the possibilities to improve the delta, are far more valuable. Life cycle assessment (LCA) and other related methodologies are a continuously evolving science, and the studies produced are time-point, market, and region specific. It is therefore difficult to compare across studies with any degree of certainty. The carbon footprint of beef production has been quantified using LCA in the United States, Canada, Brazil, Sweden, Australia, and Japan (Figure 3). However, variation in methodologies, boundaries, and time points for each system render direct comparisons impossible. The need for a coordinated international methodology has been noted by many industry groups and nongovernmental organizations, yet LCA and other methods are still in developmental infancy, with significant data gaps. The urgency of current consumer, retailer, and policy-maker concerns relating to the carbon footprint of animal production suggests that rather than waiting for the science to evolve further, systems and management practices that mitigate carbon emissions based on credible science and biology should be implemented immediately.

CONCLUSION

It is clear that the livestock industry faces a challenge in producing sufficient animal protein to supply the needs of the growing global population while reducing the environmental impact. The most significant question

facing the beef industry is therefore how to overcome the popular perception of modern agriculture as being environmentally unfavorable. Improved management, nutrition, and genetics have considerably reduced resource use and waste output per unit of beef over the past 30 yr. The reduced resource use and waste output per unit of beef associated with conventional compared with grass-fed beef production demonstrates that the popular perception of sustainable systems is very much at odds with the true picture. It is therefore imperative to educate consumers, retailers, and policy makers to ensure that access to management practices and technologies that improve productivity are not impeded in the future.

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