Sustainability: What does it mean and why does it matter?

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Introduction

The global population is expected to grow to between 9 and 10 billion persons by the year 2050, with much of the population growth occurring in developing nations and the global south (United Nations, 2013). There has been a major migratory shift of population from rural to urban environments, and now more than 50% of the world's population lives in cities (United Nations, 2014). In addition to a growing population, incomes are increasing around the world. Both growing numbers of people and increasing affluence will drive growth in demand for animal protein by an estimated 70% over the next few decades (Gerber et al., 2013). Simultaneous to increasing animal protein demand, the productivity of agriculture faces the constraints of limited resource availability (e.g., water) and global climate change and variability. With the convergence of increasing demand for food and global environmental changes, interest in sustainability and sustainable intensification of agriculture has grown.

Does sustainability equal carbon footprint?

While many agree sustainable foods systems are needed, agreement on what "sustainable food systems" are remains elusive. Much of the recent interest in sustainability pertaining to beef production has been driven by concerns regarding the environmental impact of beef production. A 2006 United Nation's Food and Agriculture Organization (UN FAO) report titled "Livestock's Long Shadow" (LLS; Steinfeld et al., 2006) was particularly influential in driving media interest in the environmental impact of beef and animal agriculture more generally. The executive summary of the 416 page report contained the following two sentences:

"*The livestock sector is a major player, responsible for 18 percent of greenhouse gas emissions measured in CO_2 equivalent. This is a higher share than transport.*"

The 18% of greenhouse (GHG) emissions figure has been extensively quoted in popular media articles and documentaries (see: http://www.cowspiracy.com/facts/). LLS used a life cycle assessment (LCA) to determine the 18% figure. LCA is essentially an accounting system that sums all GHG emissions from the entire production chain of a given product, from "cradle-to-grave." For an LCA of beef production, the GHG emissions sources can include emissions from feed production (e.g., nitrous oxide emissions from soil), emissions from the animals themselves (e.g. methane emissions from enteric fermentation), and emissions from processing and transportation (e.g., carbon dioxide emissions from burning fossil fuels). Included in LLS' LCA of global livestock production was land use change, which included desertification and deforestation. Land use change accounted for over 35% of the total estimated GHG emissions attributed to livestock in LLS (Steinfeld et al., 2006). For land use change, the lost potential of photosynthetic organisms (e.g., trees, grasses) to sequester carbon dioxide from the atmosphere is counted as a source of GHG emissions, along with any emission of carbon stored in the soil.

While land use change is a serious environmental issue, animal agriculture has not been a major driver of land use change in the United States in the past several decades (Pitesky et al., 2009). Additionally, the transportation and energy sectors in the United States generate far more GHG emissions as a percent of total GHG emissions as compared to the whole of U.S. animal agriculture. According to the most recent U.S. GHG emissions inventory, animal agriculture contributes approximately 3.6% of GHG emissions (considering enteric methane and manure methane and nitrous oxide emissions; US EPA, 2014). Fossil fuels burned for transportation and electricity contribute 30.6% and 25.8%, respectively, of total U.S. GHG emissions (US EPA, 2014). Clearly, the 18% of GHG emissions statistic from LLS is not appropriate to apply uniformly across all regions and nations around the world. To better represent the geographic variability in GHG emissions from animal agriculture, the UN FAO conducted a follow-up report that disaggregated GHG emissions from animal agriculture by region. The report found that 14.5% of global anthropogenic GHG emissions were from animal agriculture, and there was significant variation from region-to-region (Gerber et al., 2013). Indeed, the average GHG emission intensity (i.e., carbon footprint) was 46.2 kg of CO_2-equivalents[1] per kg of carcass weight of beef; however, the range was 14 to 76 kg of CO_2-equivalents per kg of carcass weight, with the lowest GHG emissions intensities found in developed nations with intensive production systems (Gerber et al., 2013; Opio et al., 2013).

Carbon footprints of beef production not only vary based on geographic location (due to differences in production systems, technologies, animal genetics, etc.), but also temporally. In the United States, advances in animal genetics, nutrition, reproduction, etc. have led to improvements in the production efficiency of beef production. Simply, production efficiency can be defined as minimizing the amount of inputs (e.g., feed, fossil fuels) and outputs (GHG emissions) to produce a given quantity of beef (Place and Mitloehner, 2010). In many, but not all cases, improvements in efficiency that beef producers have pursued to improve their business profitability and viability have translated into reductions in the carbon footprint of U.S. beef production. Rotz et al. (2013) simulated the U.S. Meat Animal Research Center’s beef production system and found that the carbon footprint was reduced 6% from 1970 to 2011. Capper (2011) estimated that the U.S. beef carbon footprint was reduced by 16% from 1977 to 2007. However, environmental sustainability encompasses more than just carbon footprint, (both Rotz et al. (2013) and Capper (2011) did estimate other categories environmental and resource use footprints, e.g., water footprint of beef), and sustainability more broadly must consider economic and social factors relating to beef production.

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[1] Different greenhouse gases have different radiant forcings, or abilities to trap heat in the Earth’s atmosphere, and different atmospheric lifetimes. To account for these differences, the Intergovernmental Panel on Climate Change (IPCC) has established global warming potentials (GWP) for each GHG on a carbon dioxide basis for a 100-year time horizon, often referred to as carbon dioxide equivalents (CO_2-equivalents). The 100-year GWPs from the 2013 IPCC report for methane and nitrous oxide are 28 and 265 respectively, without the inclusion of climate-carbon feedbacks, and 34 and 298, respectively, with the inclusion of climate carbon feedbacks (IPCC, 2013). Climate carbon feedbacks relate to the positive feedbacks during warming. For example, increased warming caused by GHG emissions can accelerate methane release from the Arctic, further accelerating the warming process.

Beef sustainability: What is it?

Sustainable development was defined in 1987 as meeting “the needs of the present without compromising the ability of future generations to meet their own needs” (Brundtland, 1987). Others have defined sustainability as meeting a triple-bottom line of balancing people, planet, and profit (Elkington, 2004). Combining these concepts, sustainable beef production can be defined as meeting current and future demand for safe, nutritious beef products while maintaining long-term business viability, stewardship of natural resources, and responsibilities to community, family, and animals. The optimum balance of the economic, environmental, and social aspects of sustainability will not be the same for each operation, due to differences across production systems including varying climates, available resources (financial capital, human capital, natural resources), and value judgements of both producers and consumers. The social aspects of sustainability are particularly hard to quantify, and thus, many of the tradeoffs and synergies between the different areas of sustainability remain unquantified, and in some cases are unquantifiable.

The definitional and quantification challenges of beef sustainability stem from beef sustainability being a “wicked problem.” Peterson (2013) outlined four distinguishing characteristics that make problems wicked as the following: (1) no definitive formulation of the problem exists, (2) its solution is not true or false, but rather better or worse, (3) stakeholders have radically different frames of reference concerning the problem, (4) the underlying cause and effect relationships related to the problem are complex, systemic and either unknown or highly uncertain. In essence, the wickedness of sustainability is due to scientific uncertainty of individual and inter-related aspects of sustainability (e.g. methane emissions from grazing beef cattle – few data exist) and differences in perspectives and values across stakeholders. For beef production, stakeholder groups are broad and extend the entire beef value chain, from beef producers, processors, retailers, consumers, as well as governmental and non-governmental organizations (e.g. World Wildlife Fund, The Nature Conservancy). Each of these stakeholders may prioritize a certain aspect of sustainability above others. For example, a consumer may value food safety and affordability as the highest priorities of beef sustainability, while an environmental group may value lowering the environmental footprint of beef production as the highest priority for beef sustainability. Transparently delineating the different values stakeholders bring to a beef sustainability discussion before advancing to sustainability “solutions” is critical to avoid intractable debates.

Context for Beef Sustainability

One of the arguments against the sustainability of beef production is that cattle are inefficient converters of feed to body weight gain, and our food systems would be more sustainable and feed more people if they included less ruminant meat products (Cassidy et al., 2013; Heller and Keoleian, 2014; Stehfest et al., 2009). The trade-offs of dietary switches are often calculated by assuming pasture and cropland used for livestock production would be abandoned (Stehfest et al., 2009) or the forage component of livestock diets is simply ignored (Cassidy et al., 2013). Additionally, the byproducts of ruminant meat production (e.g., leather) are often assumed to be replaced without consideration of the environmental impact of the alternatives (Stehfest et al., 2009) or are not considered (Cassidy et al., 2013). These assumptions and omissions likely limit the usefulness of the conclusions that can be drawn from such analyses, though, to be fair, accurately modelling the environmental impacts of the global food system or consequences of dietary shifts is a nearly impossible task due to the complexities and uncertainties involved. Nonetheless, improving feed conversion efficiency is a key area of opportunity to improve the sustainability of beef production. Enhancing feed conversion efficiency has often focused on improving individual animal performance of confined feedlot cattle fed total mixed rations. However, improving and selecting for more feed efficient cattle in the feedlot may increase mature cow size and increase the feed requirements of the U.S. cow herd. Considering the entire beef value chain's feed conversion efficiency (total feed resources required by all animals in the seedstock, cow-calf, stocker, and feedlot phases/total live weight gain of animals destined for slaughter), improving feed conversion efficiency may become more complex. For example, the reproductive efficiency of cow herd could significantly impact the size of the supporting herd (cows, heifers), and consequently feed resources, required to produce a given amount of beef; therefore, improvements in the calf crop should have positive implications for whole herd feed conversion efficiency.

Fundamentally, the beef industry is about converting natural resources of lower human value to higher human value products. Less than 1% of the solar energy that reaches Earth is captured by photosynthetic organisms, which is the energy that allows all heterotrophic life (i.e., non-photosynthetic, from bacteria to cattle to humans) to exist. Much of the solar energy captured by photosynthesis is in the form of the compound cellulose. Ruminants play a unique role in the food system by converting cellulose, which is indigestible by humans and the most abundant organic (carbon-containing) molecule on Earth, into high quality animal protein and ancillary products (e.g., leather). The monogastric animal industries (e.g., poultry, swine) have a limited capacity to use high cellulose-containing forages and by-product feeds (e.g., almond hulls, cottonseed), so while those species (and fish) may be more efficient when expressing feed efficiency as feed-to-gain, consideration should be given to the conversion of human inedible-to-human edible energy and protein.

Oltjen and Beckett (1996) evaluated dairy and beef cattle systems using a costs and returns analysis of humanly edible energy and protein. Humanly edible returns for digestible energy ranged from 37 to 59% and returns to digestible protein ranged from 52 to 104% depending on the time spent in the feedlot and the feedstuffs used (increasing amounts of corn in the diet lowered the returns on humanly edible inputs, and increasing the use of by-products increased the return to humanly edible inputs; Oltjen and Beckett, 1996). Wilkinson (2011) found similar results when evaluating the human edible energy and protein conversion efficiencies of U.K. beef systems, with increasing incorporation of cereal grains into the diets of beef cattle resulting in poorer conversion efficiencies. A tradeoff of increasing forage in the diets of cattle is those diets result in higher enteric methane emissions (Johnson and Johnson, 1995). Additionally, ruminants can add value to agricultural systems by preventing permanent grasslands from being converted to cultivated cropland and by incorporating forages into crop rotations, both of which can improve soil conservation and health. Rangelands (approximately 50% of the Earth's land surface, much of which is unsuitable for cultivation) and human inedible by-products will always be an important part of our agricultural system; therefore, cattle and other ruminants play an important role in enhancing nutrient recycling in our food system.

The argument that beef production, due to its inefficiencies, negatively impacts food security misses many of the complicated factors that influence food security. Food security for current and future generations is often used as a major justification for increasing the productivity of agricultural production. Indeed, food security is a critical issue in the United States and around the world. In 2013, 14.3% of all U.S. households and 19.5% of U.S. households with children were estimated to be food insecure (Coleman-Jensen et al., 2014). Food insecurity in the United States is defined as reduced food intake and disrupted eating patterns at times during the year due to a lack of money and other resources for food (Buzby et al., 2014). Globally, approximately 1 in 9 persons, or 802 million people, suffer from chronic undernourishment (FAO, IFAD and WFP, 2014). A logical conclusion upon first observing the number of food insecure persons is that we must produce more food to meet their needs. Increased food production is certainly a component of the solution to food insecurity; however, food security is far more complicated that simply producing enough food to meet the needs of the global population. For example, it is estimated that 30% of edible food and approximately 20% of the global meat supply is wasted throughout the production chain (UN FAO, 2015). In the United States, an estimated 31% of the edible food supply and 27% of meat is wasted (Buzby et al., 2014). Based on the proportion of food wasted, it seems current levels of food production in the world would be able to meet the needs of the global population if there was no waste. However, food security is more complicated than a simplified equation of food security = [calories produced]/ [calories required by the human populace]. Food and nutritional security depend on availability and access to food. Physical infrastructure (transportation systems, refrigeration), market infrastructure, incomes, political stability, etc. all play important and interrelated roles in determining how food secure a population is, whether considering the United States or any other nation in the world. Consequentially, during discussions of the role of intensification and increasing productivity of beef production, and agriculture more broadly, the nuance and complicated nature of food security should not be ignored to justify certain production systems or technologies.

Conclusion

Clearly, sustainability is important to the beef industry, with the U.S. Dietary Guidelines Advisory Committee including sustainability in their draft report of the 2015 Dietary Guidelines and major retailers like Wal-Mart seeking sustainable products to sell in their stores. Improvements in production efficiency are associated with decreases in environmental footprints, which translates into potential win-win scenarios where producers can improve economic and environmental sustainability simultaneously. In the face of increasing global protein demand, further improvements in the production efficiency of the beef system will be necessary to meet demand and minimize the environmental footprint of beef. However, the social acceptability of production practices must be considered. Approximately 2% of Americans are agricultural producers, but 100% of the population are eaters – the values and concerns of the public cannot be ignored. Finally, there are significant data gaps and uncertainties related to beef sustainability, particularly related to the tradeoffs and synergies across the economic, social, and environmental indicators of sustainability, which should be remedied with research and respectful dialogue among members of the beef value chain.

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