Environmental Impact of Beef Cattle Production Systems[1]

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Beef Demand in the Context of a Growing Population

As we move toward the next couple of decades, the world's agriculture will face one of the greatest challenges of all time: to produce enough food to feed the 9 billion people the earth will hold by 2050. Without question, this will demand the concerted efforts of producers, researchers, and policymakers to provide the experience, technology, and legal framework necessary to accomplish such a difficult endeavor. Among the different sources of animal protein, beef is the most nutrient dense on a per calorie basis, supplying several of the essential vitamins and minerals with a relatively low caloric intake per serving (McAfee et al. 2010). A controlled clinical study published in the *American Journal of Clinical Nutrition* showed that inclusion of lean beef in a heart-healthy diet elicited favorable effects on cardiovascular disease risk factors, helping to clarify some misconceptions related to beef consumption and health concerns (Roussell et al. 2012). This study is available via open access at http://ajcn.nutrition.org/content/95/1/9.full?sid=1352b733-d9e4-4961-a1ff-dff8927e8d87.

Amongst the different types of animal proteins, beef has been historically priced higher on a per weight basis. However, the price of beef relative to other proteins is not entirely due to cost of production. Beef prices are highly influenced by consumers' preferences and supply/demand forces controlled by several factors, many of which are beyond the control of producers and consumers. To illustrate this point, consider the current trends in animal protein consumption in Asia. China hosts 20% of the world population with only 7% of the world's land area, and a growing economy that is demanding more beef (Cao and Li 2013). Early projections of global meat consumption by Bradford (1999) indicated that meat consumption in China was going to increase by 91% from 1993 to 2020. Now that we are 6 years from 2020 we can see that the predictions were accurate. Moreover, newer projections indicate that, specifically for beef consumption, China will have an increase of 4.2 lb per capita for the period 2010–2025 (Table 1). While this increase may not seem significant, given the population in China, this translates into an extra 2.5 million metric tons of beef that will need to be produced in a period of 15 years.

In conclusion, with the exception of certain cultures, beef is commonly the protein of choice as average income increases. For the reasons stated above, beef demand is likely to continue increasing as economies continue to

1. This document is AN302, one of a series of the Animal Sciences Department, UF/IFAS Extension. Original publication date November 2014. Visit the EDIS website at http://edis.ifas.ufl.edu.

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Table 1. Consumption of beef meat and total meat per capita (kg) for 2010 and projected for 2025

	Beef				Total Meat		
Country	2010	2025	2025/2010		2010	2025	2025/2010
Argentina	55.7	55.2	−0.5		96.2	106.4	+10.2
Brazil	39.8	49.1	+9.3		94.0	106.9	+12.8
United States	38.2	38.0	−0.1		109.2	109.0	−0.1
Australia	35.3	34.7	−0.7		92.7	96.7	+4.0
EU-27	16.4	16.0	−0.4		77.7	80.1	+2.4
Russia	16.0	16.5	+0.4		56.1	67.3	+11.2
Japan	9.5	11.6	+2.1		44.7	50.6	+5.9
China	4.2	6.1	+1.9		53.0	72.9	+19.9
India	1.8	2.0	+0.2		4.1	4.4	+0.3
Source: Adapted from Hocquette and Chatellier (2011)							

develop throughout the world, especially in emerging countries (Bradford 1999; Hocquette and Chatellier 2011; Cao and Li 2013). Considering the cost of protein production, nutritional value, and environmental impact, some may argue that policies need to be developed to increase the consumption of insects, which are quite abundant, high in protein, and produced at low cost. Currently, the lack of consumer preference and acceptance of alternative protein sources make this unlikely. This example shows that the demand side of the equation cannot be forced and, within limits, consumer preferences have to be respected. Instead of concentrating the efforts in modulating or restricting the demand of beef, the policy makers, researchers, educators, and beef producers could concentrate efforts on increasing the sustainability of beef production to meet a growing demand.

Beef Production's Greenhouse Gases and Their Effect on the Environment

The "greenhouse effect" of certain gases refers to their ability to "trap" the heat that is generated when the sun radiation bounces back after hitting the earth's surface. That radiation cannot escape, and thus increases the atmospheric temperature, affecting biological processes in diverse manners. Those gases with such capacity to retain heat are called Greenhouse Gases (GHG), and the three most common gases are carbon dioxide, methane, and nitrous oxide. The effectiveness of each of the gases at trapping heat, as well as their lifetime in the atmosphere, are used to calculate what is called the global warming potential (GWP) of each gas, a relative unit that allows comparison across GHG. As a result, the GWP of each of the three main gases are 1, 25, and 298 for carbon dioxide, methane, and nitrous oxide, respectively. For inventory purposes and in policy making, calculations of GHG emissions are expressed in terms of carbon dioxide equivalents, using the emissions of each GHG and the GWP for conversion.

Greenhouse gases are only one of the environmental concerns with beef production. Other environmental concerns of cattle production are water usage, ammonia emissions, volatile organic compounds, and hydrogen sulfide production (Neumeier and Mitloehner 2013). The efficiency of water usage in agricultural systems has been debated extensively, and a more efficient water usage is rapidly becoming a priority. However, in 1977 vs. 2007, the water footprint (amount of water needed per unit of beef produced) was reduced by 12.1%, mainly due to technological improvements in efficiency of water use by crops and of feed use by animals (Capper 2011). But currently the primary focus of research is on greenhouse gas emissions, and thus that will be the focus of this discussion.

The Great Advantage of Ruminants

Ruminants such as cattle, sheep, and goats have a unique advantage over non-ruminants in terms of nutritional physiology, because they carry microorganisms in their gastrointestinal tract (GIT) that hold the key to the digestion of fiber. Fiber is present in forages in the form of cellulose and is the most abundant complex carbohydrate on earth. By harboring microorganisms in their GIT, ruminants can take advantage of fiber digestion by creating a symbiotic relationship between the microbes and the ruminant host. The microbes digest the fiber and produce by-products known as volatile fatty acids, which are in turn used by the ruminant animal as an energy source. In return, the ruminant host provides a good environment for the microorganisms and plenty of feed to sustain their growth. For this reason, cattle, sheep, and goats can thrive in environments where no other type of production system can take place.

Non-ruminants, such as poultry and swine, do not have the ability to digest fiber and rely on the use of grain and protein supplements to achieve high production levels. While poultry and swine production systems compete directly with humans for the type of feed used (i.e., plant proteins and cereal grains), they efficiently convert that feed into animal protein. Thus, ruminants grazing in areas where no crops can be grown and no other livestock species can survive represent an excellent opportunity to maximize land use, and provide nutrient recycling in the form of manure. Moreover, combinations of cattle grazing and row crops in a rotational manner has proven to be highly beneficial to increase yields, improve soil health, and increase the sustainability of production systems (Katsvairo et al. 2006).

Around the world, the initial phases of the beef production cycle (cow/calf and stocking segments) are almost entirely reliant on the use of forages or fibrous by-products, and this often takes place on land where no other production system can strive. In particular, the cow/calf segment in Florida takes place mostly under native vegetation and range conditions, which provide wildlife habitat for endangered and non-endangered species. This contribution of beef cattle systems in the form of ecosystem services is often overlooked. Additionally, beef and dairy cattle are particularly efficient at recycling by-products of agriculture industries that are not suitable for consumption by other livestock species. Examples include the use of citrus by-products, distillers grains (by-product from ethanol), and corn gluten feed (residue from wet milling of corn to produce high fructose corn syrup). Currently, no studies have attempted to put a value on the ability of ruminants to convert fiber to human food, because of the difficulty in quantifying this function of ruminant animals to society. However, Liska et al. (2009) calculated a greenhouse gas emissions credit of 29% of total emissions to ethanol production for utilization of fibrous by-products by beef cattle. In other words, using by-products of the ethanol industry to replace corn as cattle feed decreases the carbon footprint of beef production. In this case, the utilization of the ethanol by-product by cattle reduces the greenhouse gas emissions associated with ethanol production for fuel and converts the waste product into human food. Future research should address and quantify the value of this function of ruminant animals to society.

Another advantage of pasture ecosystems is that they may also act as a carbon sink, helping to offset GHG emission by grazing animals. In fact, grasslands are among the largest ecosystems in the world (61.2 million km^2) and provide numerous ecosystem services (Reid et al. 2008). Soil organic matter (SOM) of terrestrial soils contains 3,000 to 5,000 billion metric tons of carbon compared to 700 and 480 billion metric tons in the atmosphere and in plant/animal biomass, respectively (Stevenson and Cole 1999). These numbers indicate the importance of SOM as a carbon sink and the role of grassland in carbon sequestration. Fisher et al. (1994) suggested that deep-rooted grasses are a substantial “missing sink” of 0.4–4.3 billion metric tons per year in global carbon budget. Soussana et al. (2010) also indicated that grassland carbon sequestration has a strong potential to partly mitigate the GHG balance of ruminant production systems.

Generating Accurate Greenhouse Gas Emissions Estimates

Accurately quantifying the contributions from the different sectors to global GHG is critical for the development of policies to mitigate the impact of GHG on the environment. One of the early reports of global greenhouse gas emissions produced by FAO in 2006 indicated a contribution of 18% of the emissions by the livestock sector alone, when all sources of emissions were considered in a life-cycle assessment. These calculations resulted in greater emissions from livestock production than for the transportation sector, which was an overestimation. The erroneous approach used for the 2006 FAO report (called *Livestock’s Long Shadow*), was pointed out in a peer-reviewed scientific journal article by Pitesky et al. (2009). One of the main sources of error in the report included accounting for all indirect emissions in the production of animal proteins (e.g., transportation, harvesting, feed), while only direct emissions by fossil fuel burning were considered for the transportation sector. This means that important sources of GHG emissions such as the carbon footprint of car manufacturing, fossil fuel extraction, and fossil fuel processing were left out of the life-cycle assessment for the transportation sector. All this contributed to an overestimation of livestock emissions by a factor of 5 (3.3% of the total emissions according to EPA vs. 18% according to the FAO report; Pitesky et al. 2009).

Unfortunately, despite the admission of the mistake and the subsequent reporting of corrected estimates of GHG emissions by the US-EPA, this inflated figure continues to be cited today in many respected journals, including the *Proceedings of the National Academy of Sciences*.

Greenhouse Gas Emissions by Economic Sector

As an example (Fig. 1), in 2012 the total GHG emissions in the United State were 6,525 million metric tons (MMt) of carbon dioxide equivalents per year, while the amount of GHG emissions from agriculture was 614 MMt (9.5% of total U.S. emissions; EPA 2014). Further dissecting the emissions in the agricultural sector (Fig. 2), we can observe that the contribution from livestock (all species included) is of 34.5% of the total agriculture GHG emissions. *Thus, the contribution of the livestock segment to total US greenhouse gas emissions in 2012 was 3.3%*. These emissions contrast notoriously with those by the transportation segment (28.4% of total) and by electricity generation (31.9% of total US emissions). These relative contributions by sectors could be considered by policymakers when designing strategies that can have a meaningful impact on mitigation of GHG emissions.

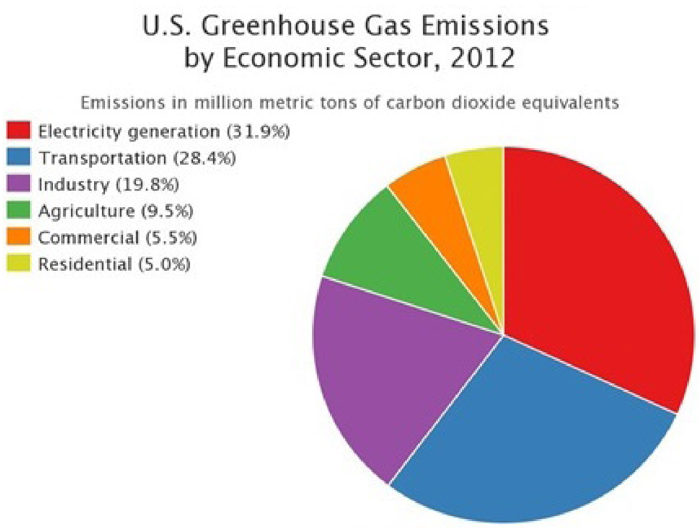

Figure 1. US greenhouse gas emissions by sector
Credits: National Greenhouse Gas Emissions Webpage Interactive Tool (EPA 2014)

Mitigation Strategies

There are plenty of opportunities for mitigation of GHG emissions from animal production, and that is one of the active areas of research at the University of Florida. In addition to the environmental benefit, a reduction in GHG emissions is likely to yield an improvement in productivity and profitability of the operation. Some of the mitigation strategies being researched at the University of Florida involve management practices (stocking rate, level and type of feed supplementation), forage types, genetic selection for improved feed efficiency, and feed additives aimed at decreasing methane emissions. Perhaps one of the most successful ways to minimize the environmental impact is to increase productivity and thus decrease the GHG emissions per unit of animal protein produced (Hristov et al. 2013b). To mitigate methane emissions due to feed digestion processes (often called "enteric fermentation") several approaches have been attempted by modifying digestion processes with more or less success (Monteny et al. 2006; Hristov et al. 2013a). A review by Havlik et al. (2013) was published in the Proceedings of the National Academy of Sciences analyzing the economic and environmental impact of mitigation strategies and climate policies. This study is available for free via open access at www.pnas.org/cgi/doi/10.1073/pnas.1308044111. One of the main conclusions by Havlik et al. (2013) is that "[s]tringent climate policies might lead to reductions in food availability of up to 200 kcal per capita per day globally. We find that mitigation policies targeting emissions from land-use change are 5 to 10 times more efficient—measured in 'total abatement calorie cost'—than policies targeting emissions from livestock only."

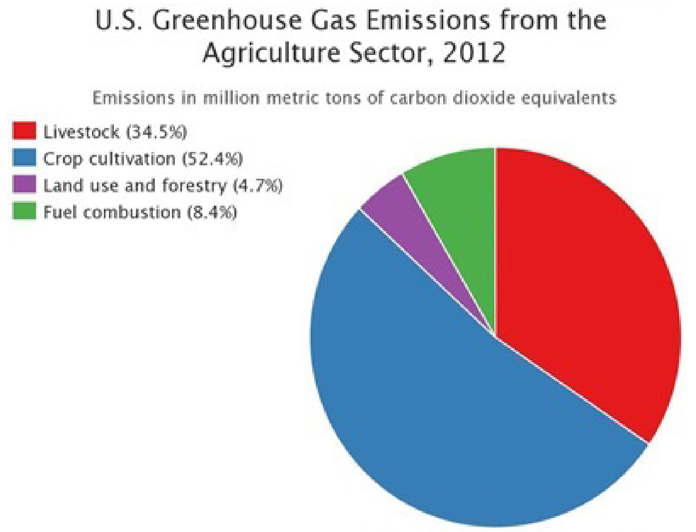

Figure 2. Breakdown of US greenhouse gas emissions within agriculture sector in 2012
Credits: National Greenhouse Gas Emissions Webpage Interactive Tool (EPA 2014)

Cattle ranchers and farmers rely heavily on their natural resources for their livelihood, and fewer resources are being used now by cattle ranchers and farmers than in the 1970s. For example, in 2007 to produce the same amount of beef, cattle ranchers and farmers needed 69.9% of the animals, 81.4% of feedstuffs, 87.9% of the water, and only 67% of the land that was used in 1977 (Capper 2011). This example shows how much the adoption of technology has helped to minimize the environmental impact of food production.

Summary

- Efforts in policy making, research, and production could concentrate on improving the efficiency of production rather than attempting to alter the demand of animal proteins.
- Cattle can thrive and reproduce in environments where other domesticated animals cannot, because of their ability to consume forages as the only dietary ingredient.
- Beef production provides a high-quality animal protein.
- Beef cattle are very efficient at recycling nutrients through manure, and by using fibrous by-products that may otherwise be a "waste" of agricultural industries (e.g., citrus, distillers grain, corn gluten feed, cotton by-products).
- The contribution of the livestock sector, both beef and dairy, to total US greenhouse gas emissions is 3.3% (US-EPA 2014) and not 18% as it was erroneously calculated in 2006 (FAO 2006). This overestimation was pointed out in a peer-reviewed scientific journal (Pitesky et al. 2009) and recognized by the authors of the original FAO report.
- Greenhouse gas emissions mitigation strategies are being developed by researchers. The potential of some of those strategies has been documented in scientific journals, and, in many cases, emissions reductions are accompanied by an increase in production efficiency (by decreasing a source of energy waste).
- A greenhouse gas emissions credit (reduction) of 29% of total emissions is applied to ethanol production for utilization of fibrous by-products by beef cattle. By-product feeds high in fat content, such as distillers grains derived from ethanol production, reduce methane emissions while providing a high quality feed to cattle.
- To produce the same amount of beef in 2007 that we did in 1977, we needed 69.9% of the animals, 81.4% of feedstuffs, 87.9% of the water, and only 67% of the land (Capper 2011). The adoption of technology has helped enable cattle farmers and ranchers to minimize the environmental impact of food production.

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