Executive Summary of Beef Sustainability Facts

Notes

<u>Fact Sheet Topics</u>

Summary Graphics

1. **How does the carbon footprint of U.S. beef compare to global beef?**

2. **Does beef really use that much water?**

3. **Would removing beef from the diet actually reduce greenhouse gas emissions?**

4. **How does carbon sequestration affect the sustainability of beef?**

5. Do growth promotants reduce environmental impact?

6. **Does grass-finished beef leave a lower carbon footprint than grain-finished?**

7. If we fed corn to humans instead of cattle, would land use be more sustainable?

8. Is local beef more sustainable?

9. Can different Life Cycle Assessment studies be compared?

10. How do you know if you are looking at a comprehensive and high-quality life cycle assessment study?

11. **How does animal health and welfare impact sustainability?**

12. Do feedlots have the largest greenhouse gas impact in the beef value chain?

13. How does food waste impact sustainability?

14. Are residues of the growth hormones used in cattle in our drinking water?

15. Why is sustainability so difficult to define?

16. Ecosystem Services - What are they and how do they relate to beef production?

17. What are enteric methane emissions?

18. How does beef fit into a sustainable food system?

19. How does productivity affect sustainability?

Sustainability Assessment of U.S. Beef Production

Greg Thoma, Ph.D.,[1,2] Ben Putman,[3] Marty Matlock, Ph.D.,[3,4] Jennie Popp, Ph.D.,[5] and Leah English[5]

[1]Resilience Services, LLC • [2]Department of Chemical Engineering, University of Arkansas • [3]Office for Sustainability, University of Arkansas • [4]Department of Biological and Agricultural Engineering, University of Arkansas • [5]Department of Agricultural Economics and Agribusiness, University of Arkansas

Background

With increasing public concern and awareness of agricultural sustainability issues, comprehensive methodologies such as life cycle assessment are required to benchmark the beef industry and identify areas of opportunity for continuous improvement. To that end, the Beef Checkoff completed a retrospective sustainability assessment benchmark in 2013 by using Eco-efficiency Analysis to compare the years 2005 and 2011. At the time of the analysis, the methodology used was the most up-to-date and comprehensive – indeed the analysis remains one of the only complete cradle-to-grave assessments of the U.S. beef industry. In 2015, a further refined version of the Eco-efficiency Analysis was completed to incorporate new primary data sources from the beef value chain for the years 2011-2013. As the young and dynamic field of sustainability science continues to evolve, there is a need to adapt and update the methodologies used in life cycle and broader sustainability assessments of the beef industry.

Consequently, this project updated and expanded the original Eco-efficiency Analysis to the SimaPro™ computational platform. The move to the SimaPro™ platform will allow for direct linkages with the Integrated Farm Systems Model (USDA-ARS), which is the simulation model that has been used to generate life cycle inventories from the feed production, cow-calf, and backgrounding/feedlot segments of the beef industry. Additionally, the SimaPro™ platform will allow for even more transparent reporting of our inventories and results to the broader life cycle assessment, sustainability science, and beef communities, which is key to advancing the field and benchmarking beef's sustainability. Finally, this project further expanded the economic sustainability evaluation of the U.S. beef industry to include the direct, indirect, and induced economic activity and value that is generated from beef production.

Objectives

The objective of this project was to couple farm gate environmental footprints of U.S. beef production systems with post-farm processing and distribution to provide an update to the full Life Cycle Assessment (LCA) of beef production and consumption in the United States. Specifically,

- Adapt the existing LCA to the SimaPro™ computational platform to enable comparison of future performance against the 2011 baseline.
- Collaborate with the USDA-ARS to create links between the Integrated Farm System Model and SimaPro.™
- Expand the economic analysis to include direct, indirect and induced economic activity and value added by regional beef production.

Methods

Life Cycle Assessment is a technique to assess the potential environmental impacts associated with a product or process by compiling a cradle-to-grave inventory of relevant energy and material inputs and environmental releases, evaluating the potential environmental impacts associated with identified inputs and releases, and interpreting the results to assist in making more informed decisions. Broadly, an LCA consists of four stages (**Figure 1**): 1) Define the goal and scope – including appropriate metrics (e.g. greenhouse gas emissions, water consumption, etc.); 2) Conduct life cycle inventories (collection of data identifying system inputs, outputs and discharges to the environment); 3) Perform impact assessment; 4) Analyze and interpret the results.

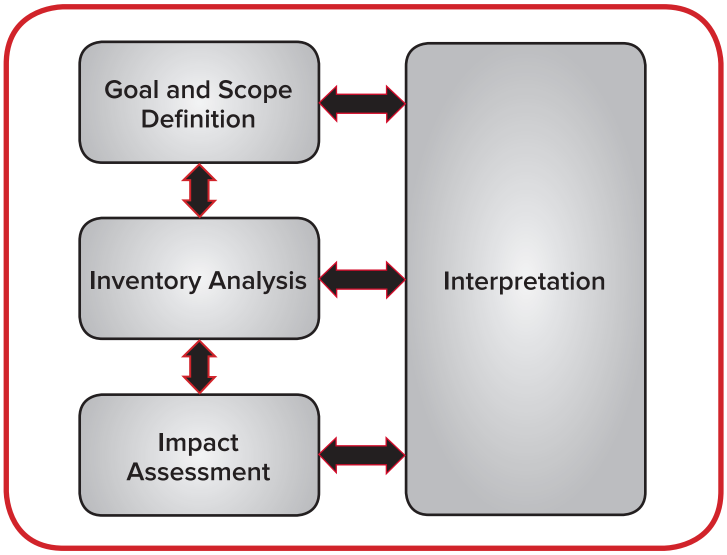


Figure 1. *Stages of life cycle assessment (LCA)*

We used data available in the first two Eco-efficiency Analysis reports as well as other publicly available data and standard computational approaches to construct a life cycle inventory model of the beef production and consumption supply chain. We replaced proprietary background data with appropriate surrogates from publicly available and transparent lifecycle inventory databases, and we adapted the life cycle impact assessment methodology used by BASF in the original Eco-efficiency Analyses as needed to the SimaPro™ modeling platform.

We used the IMPLAN multi-regional input-output model encompassing numerous aggregated sectors of the U.S. economy with state level economic transaction data to evaluate the contribution of the beef sector (production and processing) to the national economy. The model provides estimates of the direct (spending by cattle sector enterprises), indirect (non-cattle sector spending from enterprises primarily supporting cattle production), and induced (spending by wage-earning employees in the cattle sector) contributions to the economy.

Important Findings

We reproduced, using transparent and nonproprietary data sources, the major findings from the BASF report. Our results comparing the sector changes between 2005 and 2011 using both the BASF and updated lifecycle model from this work showed significant agreement both in terms of directionality and magnitude.

The relative contribution of each segment of the beef value chain to each impact category (e.g., greenhouse gas emissions, consumptive water use) were largely in agreement with the previous Eco-efficiency Analyses. For example, for both the prior analyses and the current project, 87% of carbon dioxide-equivalent emissions occurred in the pre-harvest segments of the industry, while 13% occurred post-harvest. Identifying where in the beef value chain impacts are occurring is one of the key advantages of LCA and allows the beef community to identify the areas of opportunity along the value chain. In the case of greenhouse gas emissions, the cow-calf segment is the segment with the largest contribution (**Figure 2**), with most of the segment's emissions coming from enteric methane emissions that are a part of the natural digestion process of cattle.

Additionally, LCA allows for an assessment of what impacts are within the control of beef producers, processing and case-ready plant managers, retail and foodservice operators, and consumers, and what impacts lie outside of those individuals' and entities' direct control. For

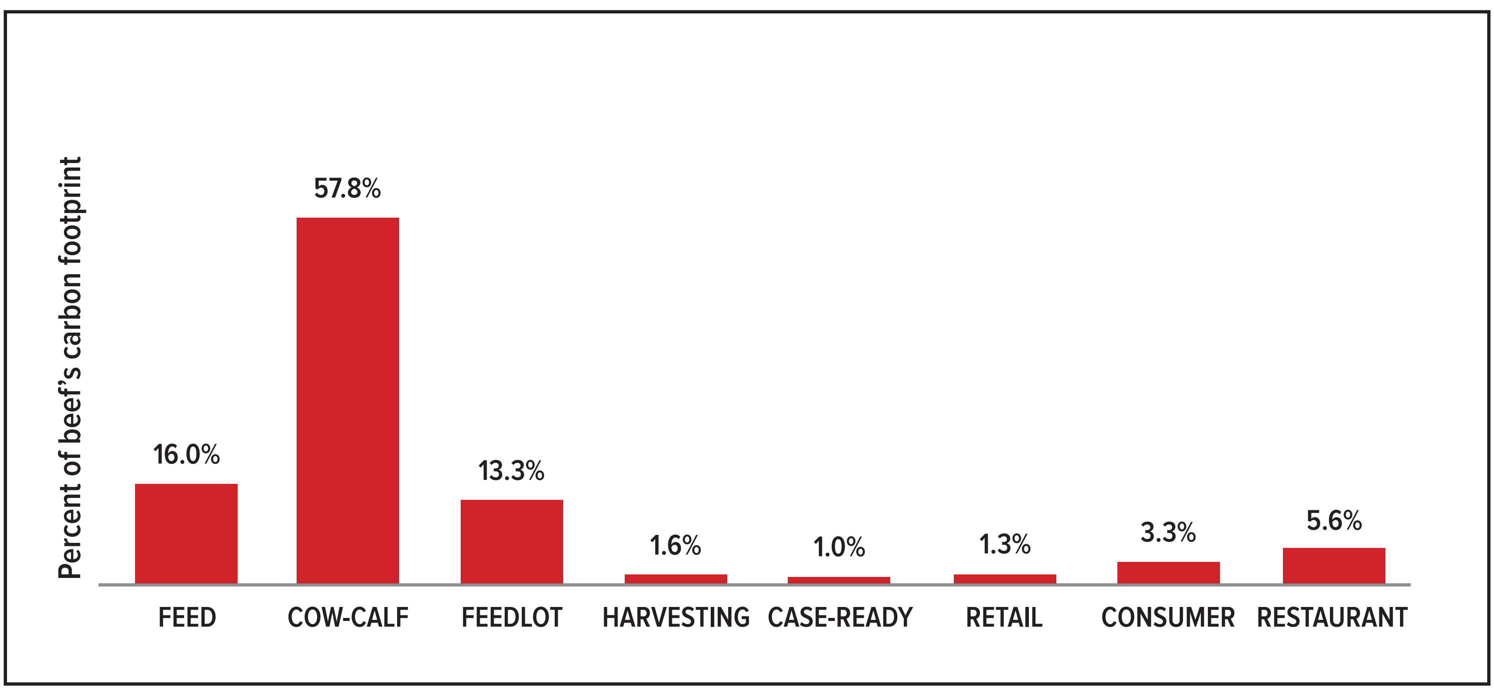


Figure 2. *The global warming potential of one pound of edible, consumed beef distributed over each segment of the beef value chain for 2011-2013. Eighty-seven percent of the CO_2 equivalent emissions from beef production occur pre-harvest, with the single largest source of emissions being enteric methane emissions.*

example, the fossil fuel combustion required to provide electricity to cow-calf and feedlot operators contributes to the acidification potential associated with beef production; however, beef producers have no control over the primary fuel sources for the electricity they purchase from a utility. Conversely, if a feedlot operator is growing a portion of the crops fed to their cattle, the operator has direct control over aspects that could reduce the impacts of feed production. Examples include changes such as adopting no-till practices, reducing synthetic fertilizer use by utilizing cattle manure as fertilizer, and improving irrigation water use efficiency.

Table 1. *The direct, indirect, and induced economic contributions[1] of the cattle industry to the U.S. economy*

Impact Type[1]	Employment	Labor Income	Total Value Added
Direct Effect	882,862	$27,600,035,580	$58,129,513,474
Indirect Effect	506,485	$27,048,925,921	$45,677,141,364
Induced Effect	709,756	$37,263,144,089	$61,597,775,670
Total Effect	**2,099,103**	**$91,912,105,590**	**$165,404,430,508**

[1]Direct = spending by cattle sector enterprises, Indirect = non-cattle sector spending from enterprises primarily supporting cattle production, Induced = spending by wage-earning employees in the cattle sector

Results of economic analysis show that, in 2014, the beef cattle production and processing industry directly contributed to the employment of nearly 883,000 workers across the United States, resulting in more than $27 billion dollars in labor income and $58 billion in value added to the U.S. economy. **When indirect and induced impacts are added, the cattle industry's total contributions to the economy more than double to almost 2.1 million jobs, $92 billion in income and $165 billion in value added** (**Table 1**). In other words, each cattle job generated almost 1.4 jobs in other industries. Each $1 of cattle industry labor income led to the creation of over $2 in labor income (often in high paying jobs) elsewhere. Finally, each $1 generated by the cattle industry led to over $1.9 added value somewhere else in the economy.

Implications

This work provides the framework for open and transparent assessment of sustainability metrics for the beef industry, and will enable rapid updating of data as well as scenario testing in the future. The new framework will allow data from the Beef Checkoff's regional sustainability assessments to be quickly integrated into the next national sustainability benchmark. This work also established the relative contribution of the beef production sector to the national and regional economies.

The latest beef sustainability assessment evaluated environmental impacts from the entire beef supply chain, including retail.

Funded by the Beef Checkoff.

For more information, contact:
National Cattlemen's Beef Association
Contractor to the Beef Checkoff Program
9110 East Nichols Avenue
Centennial, CO 80112
303.694.0305

BEEF FACTS:
SUSTAINABILITY

BEEF
RESEARCH

Fact Sheet 1 in the Series: Tough Questions about Beef Sustainability

How does the carbon footprint of U.S. beef compare to global beef?

Ashley Broocks, Kimberly Branham, Sara Place, Megan Rolf, and Michelle Calvo-Lorenzo
Oklahoma State University

The production of food in all forms results in emissions of greenhouse gases. Carbon footprints are a measure that quantify the greenhouse gas emissions that result from the production of any given food item, or for a given product, activity, or industry. A carbon footprint refers to all the greenhouse gas emissions produced and are expressed as carbon dioxide (CO_2) equivalent emissions to account for the different greenhouse gases' potential to trap heat in the earth's atmosphere. For beef production, a carbon footprint refers to CO_2 equivalent emissions per unit of beef.

Comparing the U.S. beef industry's carbon footprint to other nations is challenging for two main reasons: 1) the methodologies used in different published studies to calculate carbon footprints within and across nations vary in ways that can influence their estimated carbon footprint, and 2) the efficiency of practices in how beef cattle are raised varies greatly across countries (i.e. productive use of resources to maximize the total amount of beef produced), and efficiency is a key driver of beef's carbon footprint. To overcome these challenges, one can examine the results from individual studies that use the same methodology to estimate CO_2 equivalent emissions across the wide range of beef production systems found in the world.

In two recent analyses of global livestock systems,[1,2] North American beef production systems (including the U.S.) were found to have some of the lowest carbon footprints. As seen in **Figure 1**, when CO_2 equivalent emissions are expressed per kg of protein, the U.S. and other developed nations have lower carbon footprints (**10 to 50 times lower**) as compared to many nations in sub-Saharan Africa and the Indian subcontinent.[2]

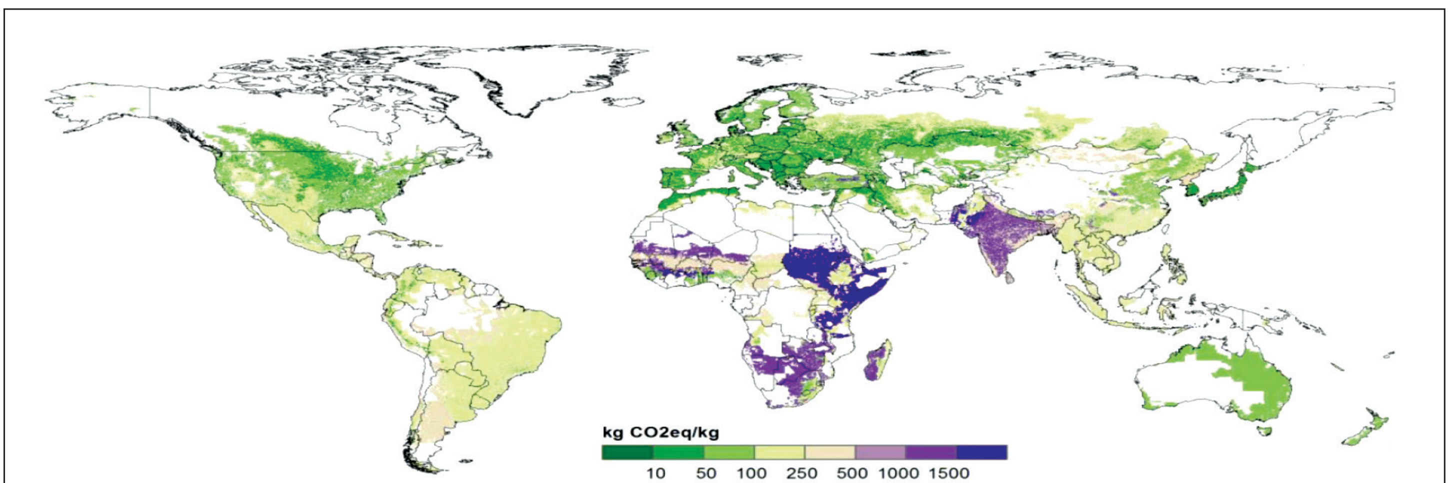


Figure 1. Greenhouse gas emissions from beef production expressed as kg of CO_2 equivalents per kg of protein. From reference 2: Herrero et al., 2013 PNAS 110: 20888-20893.

The lower CO_2 equivalent emissions per kg of protein for beef production systems in the developed world are driven by higher-quality (more digestible) feeds, lower impacts of climate stress (heat) on animals, improved animal genetics, advancements in reproductive performance, and the reduced time required for an animal to reach its slaughter weight as compared to regions with higher carbon footprints.[1,2] These heightened efficiencies have not come at the expense of animal welfare, but have accompanied a simultaneous commitment to improve the welfare of the animals. Combined, all of the above mentioned factors impact production efficiencies while decreasing the use of natural resources and the production of environmental emissions per unit of beef produced. Furthermore, it is these factors that are responsible for reducing the U.S. carbon footprint of beef by an estimated 9-16% from the 1970's to the present day.[3,4] Using management techniques and technologies developed through scientific research is key to achieving improvements in beef production efficiency and further reducing beef's carbon footprint.

***Bottom line:* The U.S. beef industry has one of the lowest carbon footprints in the world due to cattle genetics, the quality of cattle feeds, animal management techniques, and the use of technology.**

Literature Cited

[1]Opio, C., P. Gerber, A. Mottet, A. Falcucci, G. Tempio, M. MacLeod, T. Vellinga, B. Henderson, and H. Steinfeld. 2013. Greenhouse gas emissions from ruminant supply chains – A global life cycle assessment. Food and Agriculture Organization of the United Nations (FAO), Rome.

[2]Herrero, M., P. Havlík, H. Valin, A. Notenbaert, M.C. Rufino, P. K. Thornton, M. Blümmel, F. Weiss, D. Grace, and M. Obersteiner. 2013. Biomass use, production, feed efficiencies, and greenhouse gas emissions from global livestock systems. Proc. Natl. Acad. Sci. 110: 20888-20893.

[3]Capper, J.L. 2011. The environmental impact of beef production in the United States: 1977 compared with 2007. J. Anim. Sci. 89:4249-4261.

[4]Rotz, C.A., B.J. Isenberg, K.R. Stackhouse-Lawson, and E.J. Pollak. 2013. A simulation-based approach for evaluating and comparing the environmental footprints of beef production systems. J. Anim. Sci. 91(11):5427-5437.

For more information, contact:

National Cattlemen's Beef Association
Contractor to the Beef Checkoff Program
9110 East Nichols Avenue
Centennial, CO 80112
303.694.0305

Fact Sheet 2 in the Series: Tough Questions about Beef Sustainability

Does Beef Really Use That Much Water?

Ashley Broocks, Justin Buchanan, Sara Place, Megan Rolf, and Michelle Calvo-Lorenzo
Oklahoma State University

When looking for an answer to the question, "How much water is required to produce beef?" one may find a variety of answers. Water use estimates, or water footprints (defined as the amount of water used per unit of product), are available in the scientific literature and indicate that water footprints range from 317[1] up to 23,965[2] gallons per pound of boneless beef.

Why is the range so large? The range in estimates is mostly due to the methodology used by researchers. For example, some have counted all precipitation that falls on croplands, pastures, and rangelands towards the total water use of beef. Others have left out precipitation as it would fall on the land regardless of whether it was used for beef production or not. However, irrigation water use is always considered towards the total water use of beef.

Regardless of methodology, the production of feed for cattle is the single largest source of water consumption in the beef value chain (~95% of the water used to produce a pound of beef). The relative importance of this water use is highly dependent on location, because unlike greenhouse gas emissions, water use and access is a highly regionalized environmental issue. For example, in the southern High Plains approximately 30% of cropland is irrigated with water from the Ogallala aquifer.[3] In some, but not all cases, water is being drawn from the aquifer at a faster rate than it is being recharged.[3] Clearly, the use of a unit of water in such an area would be viewed and valued differently than a unit of water used in an area that primarily relies on precipitation water for agricultural production. As a result, one must be cautious about generalizing water footprints for beef or any other product on a national scale.

However, there are examples of innovative systems that integrate beef and crop production in the southern High Plains to more efficiently use water. In a four-year experiment, researchers compared a wheat-cotton crop rotation with one that integrated beef cattle, rye, wheat, and old world bluestem (a perennial warm season grass) in the High Plains of Texas. They found that the integrated beef cattle and crop system used 23% less irrigation water than the system with crops only.[4] The increase in irrigation water use efficiency was mostly due to the incorporation of perennial warm season grass into the farming system.[4] Perennial grasses would not be as valuable to sustainable farming systems without cattle that have the ability to digest such grasses because humans cannot directly consume and digest grass. While this is one example, it demonstrates that beef cattle can play a key role in water conservation.

Though the U.S. beef industry reduced its water use by 3% from 2005 to 2011,[5] many opportunities exist to further improve water use across the beef value chain (**Figure 1**). One area that is often overlooked and is important to all aspects of sustainability, not just water use, is reducing food waste. Food waste has an impact on the amount of water required to produce food for the nourishment of people. If prepared beef is thrown away and not consumed, all of the water use from feed production, cow-calf and stocker operations, feedlots, packing plants, retailers, foodservice, and the consumer has been used but has not contributed to human nourishment. Reducing food waste can help reduce the water footprint of beef and all other foods.

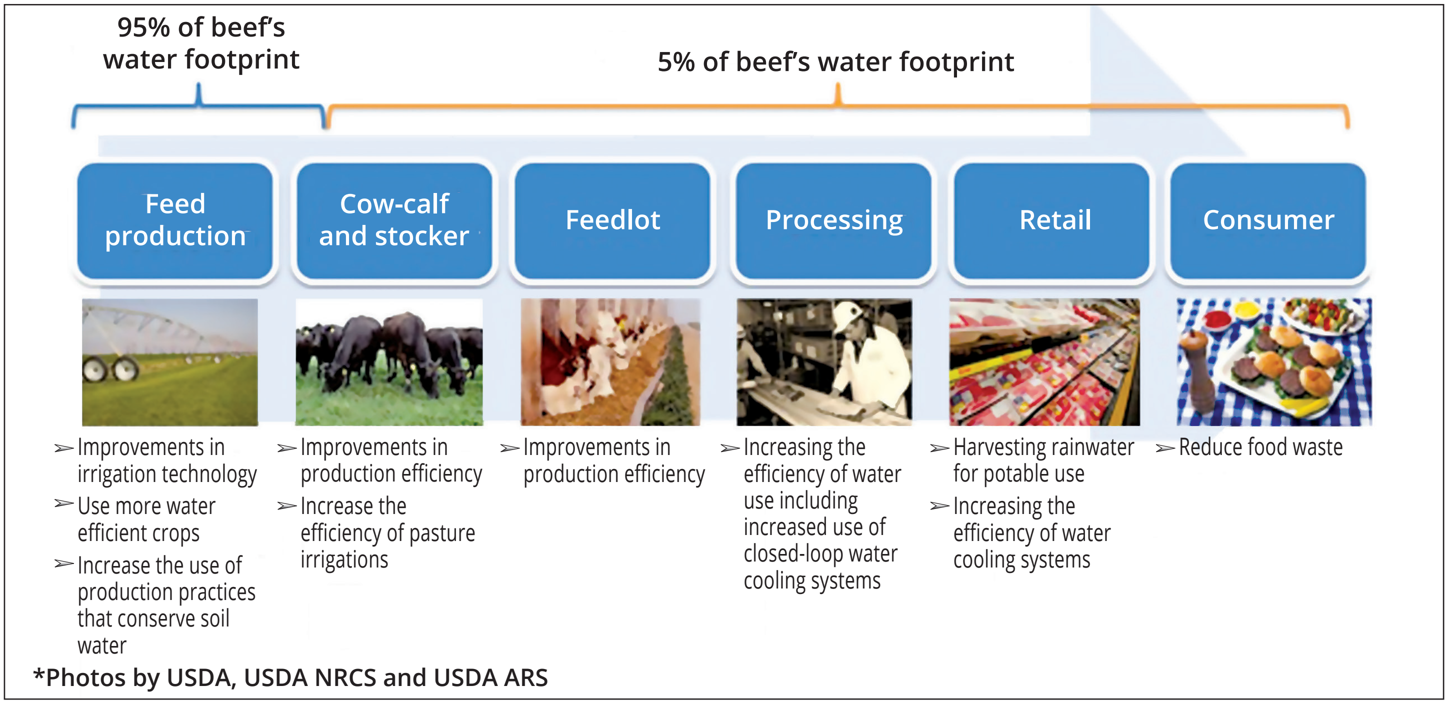


Figure 1. Examples of opportunities to reduce the water footprint of beef throughout the beef value chain.*

***Bottom line:* The estimated water required for beef production greatly depends on the methodology used in scientific calculations, especially when considering whether or not precipitation water is included in water footprints. U.S. specific estimates put beef water use at 317[1], 441[6] and 808[7] gallons per pound of boneless beef when precipitation water is not accounted for in calculations.**

Additionally, the water footprint of beef greatly depends on the amount of feed consumed by cattle because of the reliance on irrigation to produce crops (~95% of beef's water footprint). As with all food production, reducing food waste and efficiently utilizing irrigation water, particularly in water-stressed regions, is an important aspect of beef sustainability and water use.

[1] Capper, J.L. 2011. The environmental impact of beef production in the United States: 1977 compared with 2007. J. Anim. Sci. 89:4249-4261.

[2] Pimentel, D. J. Houser, E. Preiss, O. White, H. Fang, L. Mesnick, T. Barsky, S. Tariche, J. Schreck, and S. Alpert. 1997. Water resources: Agriculture, the environment, and society. BioSci. 47: 97-106.3

[3] Scanlon, B.R., C. C. Faunt, L. Longuevergne, R. C. Reedy, W. M. Alley, V.L. McGuire, and P.B. McMahon. 2012. Groundwater depletion and sustainability of irrigation in the US High Plains and Central Valley. Proc. Natl. Aca. Sci. 109: 9320-9325.

[4] Allen, V. G., C. P. Brown, R. Kellison, E. Segarra, T. Wheeler, P. A. Dotray, J. C. Conkwright, C. J. Green, and V. Acosta-Martinez. 2005. Integrating cotton and beef production to reduce water withdrawal from the Ogallala aquifer in the Southern High Plains. J. Agron. 97: 556-567.

[5] Battagliese, T., J. Andrade, I. Schulze, B. Uhlman, C. Barcan. 2013. More sustainable beef optimization project: Phase 1 final report. BASF Corporation. Florham Park, NJ.

[6] Beckett, J.L. and J.W. Oltjen. 1993. Estimation of the water requirement for beef production in the United States. J. Anim. Sci. 71:818-826.

[7] Rotz, C.A., B.J. Isenberg, K.R. Stackhouse-Lawson, and E.J. Pollak. 2013. A simulation-based approach for evaluating and comparing the environmental footprints of beef production systems. J. Anim. Sci. 91(11):5427-5437.

For more information, contact:

National Cattlemen's Beef Association
Contractor to the Beef Checkoff Program
9110 East Nichols Avenue
Centennial, CO 80112
303.694.0305

BEEF FACTS: SUSTAINABILITY

BEEF RESEARCH

Fact Sheet 3 in the Series: Tough Questions about Beef Sustainability

Would removing beef from the diet actually reduce greenhouse gas emissions?

Ashley Broocks, Emily Andreini, Megan Rolf and Sara Place
Oklahoma State University

Some have proposed that simply removing beef from the human diet could significantly lower greenhouse gas (GHG) emissions. However, upon examination of the scientific evidence, completely removing beef from the diet would likely not result in huge declines in GHG emissions, and would likely have negative implications for the sustainability of the U.S. food system.

One must first consider the amount of beef consumed by Americans. The current U.S. Dietary Guidelines for Americans recommends 5.5 ounces of lean protein per day for a person consuming a 2,000-calorie diet.[1] Beef is one of the most common sources of lean protein in the United States, with 1.7 ounces of beef per day available to U.S. consumers in 2014, as reported in USDA's Economic Research Service (ERS) Loss-Adjusted Food Availability Data Series.[2] The ERS Loss-Adjusted Food Availability Data Series is derived from ERS's food availability data by adjusting for food spoilage, plate waste, and other losses to closely approximate actual intake. Per capita beef availability (loss adjusted) has actually been declining in the United States over the past 35 years (**Figure 1**) due in part to beef production not keeping pace with U.S. population growth. Along with being a significant source of lean protein, beef provides key nutrients such as iron, zinc, and B vitamins. Removing beef from the food chain would result in consumers having to seek alternative protein and micronutrient sources, which would also have an environmental impact.

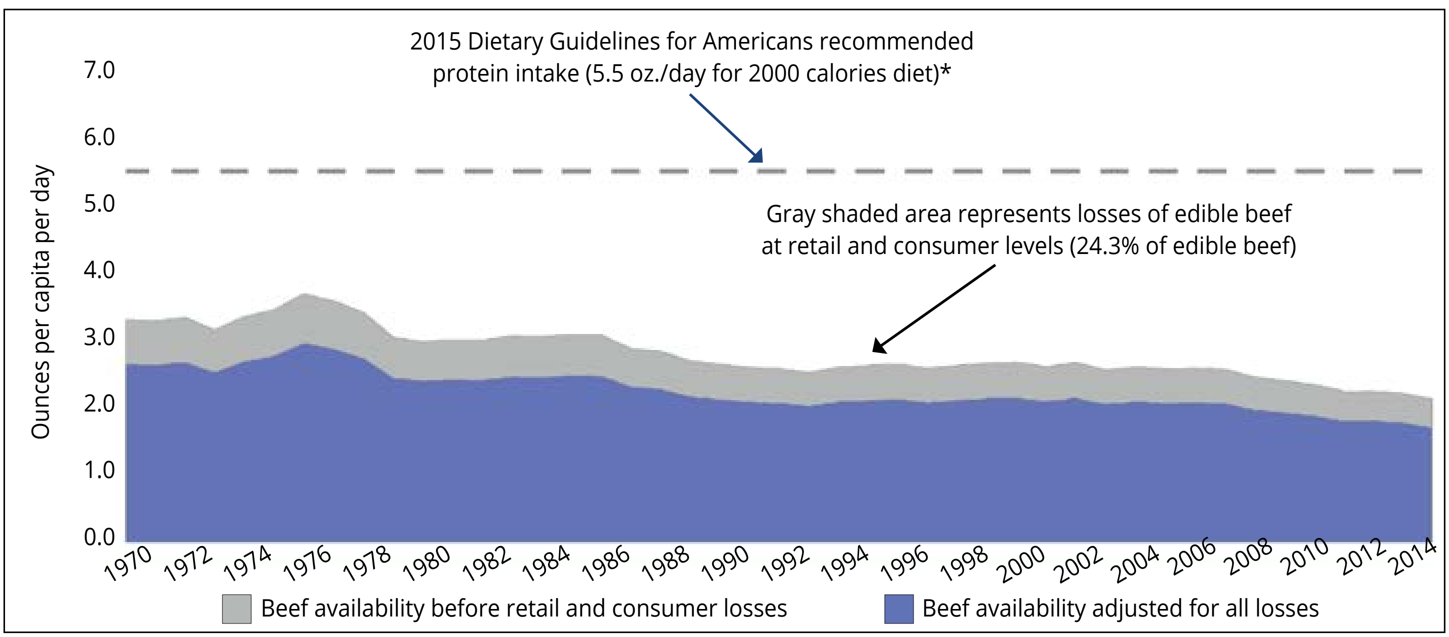
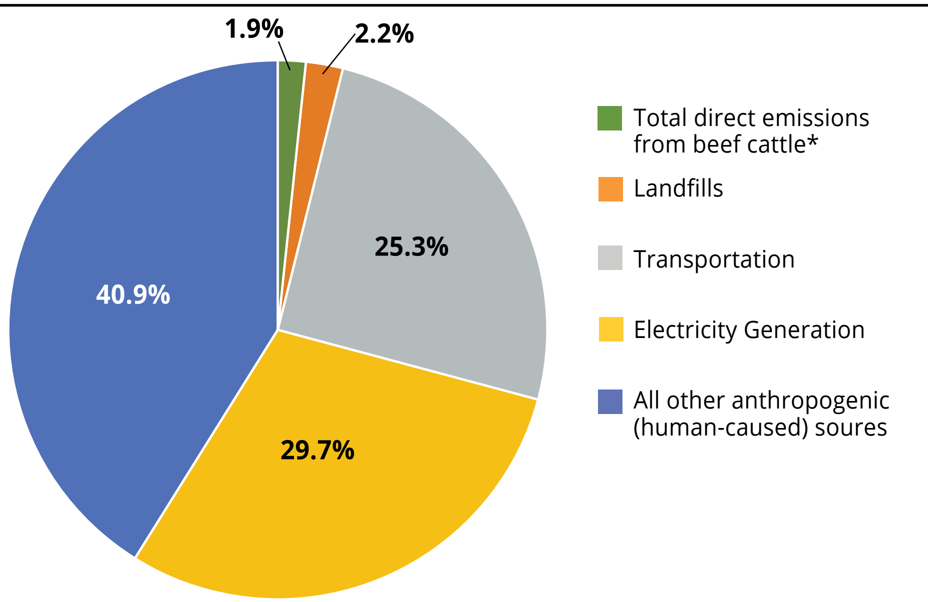


Figure 1. U.S. boneless beef availablitiy per capita[2] compared to U.S. Dietary Guidelines protein recommendations.[1]
Source: USDA-ERS. *Protein intake recommendation includes: meats, poultry, eggs (3.7 oz. - eqld),seafood (1.1 oz. - eqld), nuts, seeds, soy products (0.7 oz. - eqld).

According to the U.S. Environmental Protection Agency (EPA), beef cattle production was responsible for 1.9% of total U.S. GHG emissions in 2014.[3] By comparison, GHG emissions from transportation and electricity accounted for 25.3% and 29.7% of total U.S. GHG emissions in the same year (**Figure 2**).[3] Comparing food production (essential for human life) to transportation and electricity (non-essential for human survival, but important to our modern lifestyles) is problematic. However, the comparison is instructive because though electricity and transportation produce much of the GHG emissions in the United States, most people do not call for the elimination of electricity or transportation. Rather, efforts are made to lower the GHG emissions produced to provide the same energy and transportation services (e.g. switching to renewable energy sources for electricity generation). Using this frame of reference, another way to consider GHG emissions from beef production would be, "How can the same amount of human nutritional value be produced by the beef system while producing fewer GHG emissions?" Studying the different ways inputs (feed, water, and land) can be used more efficiently throughout the beef value chain to reduce GHG emissions per pound of beef would provide the means to maintain the same level of food production while reducing GHG emissions. Over time, beef production has made impressive advances to meet the protein demands of a growing population while reducing the amount of natural resources required to produce a pound of beef.[4,5,6] For example, due to improved genetics (of cattle and the plants they consume), animal nutrition, management, and the use of growth promoting technologies, the U.S. beef industry has decreased its GHG emissions per pound of beef 9-16% from the 1970s to today.[5,7] Further improvements in the efficiency of beef production are being continuously evaluated and researched at universities and research institutions, in the United States and globally.

Another key component of reducing GHG emissions from the whole beef system is the role of the consumer. Over 20% of edible beef is wasted at grocery stores, restaurants, and in the home (**Figure 1**).[8] As with other foods, the amount of non-renewable resources used and the environmental impacts that went into producing the portions of beef that are being sent to a landfill are often overlooked. Consumers could improve beef sustainability by 10% if beef waste were reduced by half.[8]

Beef production makes many positive contributions to the sustainability of our food system that are often overlooked by analyses of GHG emissions' impact of removing beef from the diet. Cattle have the ability to utilize forages (e.g., grass) and by-products (e.g., distillers grains) that are unfit for human consumption. Specifically cattle can utilize cellulose, one of the world's most abundant organic (carbon containing) molecules, that is indigestible by humans.[6] Consequently, U.S. beef producers feed their cattle feed sources that are not in direct competition with humans and/or would have gone to waste (by-products).[6] Cattle can also convert low-quality feeds into high-quality protein from land not suited for cultivation, thereby reducing soil erosion and enhancing soil carbon storage.[6] Furthermore, integrated crop and beef systems (e.g., using cattle to graze crop residues and cover crops) can lead to many positive environmental sustainability outcomes including increased soil water-holding capacity and enhanced nutrient cycling.[9]



* Includes all methane and nitrous oxide emissions from enteric fermentation and manure

Figure 2. 2014 Greenhouse Gas Emissions in the United States.[3]
Source: US EPS GHG Emissions Inventory, 2016

***Bottom Line:* Beef is a valuable asset to the human diet; it is an affordable, nutrient-dense source of lean protein. As with the production of all foods, the production of beef results in**

GHG emissions; however, direct emissions from the U.S. beef industry are only estimated to be 1.9% of the total U.S. GHG emissions.[3] Thus, even without consideration of the unintended consequences and impacts of alternative protein sources, completely removing beef from the U.S. diet would likely have a minimal impact on GHG emissions. However, as historical progress has demonstrated (GHG emissions per lb. of beef have been reduced 9-16% since the 1970s[5, 6]), there are opportunities to reduce beef's impact, chief among them being reducing consumer waste.

Literature Cited

[1]USDA. 2015. Dietary Guidelines for Americans. Available from: http://health.gov/dietaryguidelines/2015/guidelines/

[2]USDA. 2014. Food Availability (Per Capita) Data System. Available from: https://www.ers.usda.gov/data-products/food-availability-per-capita-data-system/food-availability-per-capita-data-system/#Nutrient%20Availability

[3]EPA. 2015. U.S. Greenhouse Gas Inventory Report: 1990-2014. Available from: http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html

[4]Capper, J.L. and D.J. Hayes. 2012. The environmental and economic impact of removing growth-enhancing technologies from U.S. beef production. J. Anim. Sci. 90:3527-3537

[5]Capper, J.L. 2011. Environmental impact of beef production in the United States: 1977 compared with 2007. J. Anim Sci. 89:4249-4261.

[6]Oltjen, J.W. and Beckett, J.L. 1996. Role of ruminant livestock in sustainable animal agricultural systems. J. Anim. Sci. 74:1406-1409.

[7]Rotz, C.A., B.J. Isenberg, K.R. Stackhouse-Lawson, and E.J. Pollak. 2013. A simulation-based approach for evaluating and comparing the environmental footprints of beef production systems. J. Anim. Sci. 91:5427-5437.

[8]Beef Checkoff. 2014. Sustainability Executive Summary. Available from: http://www.beefresearch.org/CMDocs/BeefResearch/Sustainability%20White%20Papers%20and%20Infographics/SustainabilityExecutiveSummaryWeb1.pdf

[9]Sulc, R. M. and A. J. Franzluebbers. 2014. Exploring integrated crop-livestock systems in different ecoregions of the United States. Europ. J. Agronomy. 57:21-30.

For more information, contact:

National Cattlemen's Beef Association
Contractor to the Beef Checkoff Program
9110 East Nichols Avenue
Centennial, CO 80112
303.694.0305

BEEF FACTS:
SUSTAINABILITY

BEEF
RESEARCH

Fact Sheet 4 in the Series: Tough Questions about Beef Sustainability

How does carbon sequestration affect the sustainability of beef?

Ashley Broocks, Sara Place and Megan Rolf
Oklahoma State University

Carbon is one of the most common elements on earth and is essential for life. Carbon sequestration refers to the long-term capture and storage of carbon from the atmosphere (typically carbon dioxide, CO_2). Enhancing biological carbon sequestration in soil and plants is a promising method of reducing greenhouse gas (GHG) emissions and combating climate change. Anthropogenic or human activities such as burning fossil fuels and land use changes (e.g., deforestation, and the tillage of native grasslands for crop production) have led to an increase in atmospheric concentrations of carbon dioxide (a GHG) since the beginning of the industrial revolution. Carbon dioxide atmospheric concentrations have risen from their pre-industrial level of 280 parts per million (ppm) to over 400 ppm today.[1] The increase in concentrations of carbon dioxide and other GHGs in the atmosphere has contributed to global climate change and variability.

The carbon cycle (**Figure 1**), like any other naturally-occurring process, involves a cyclical recycling, storage, and use of a resource in different states. Carbon reservoirs, where carbon is stored, include oceans, soil, and vegetation. Plants take in sunlight and carbon dioxide to synthesize carbon-containing sugars and other carbohydrates during photosynthesis. Plants, animals (including humans), and soil microbes consume molecules containing carbon for energy and release some of the carbon back into the atmosphere in the form of carbon dioxide during the process of aerobic respiration. Organic carbon from animal waste and decaying plants is stored

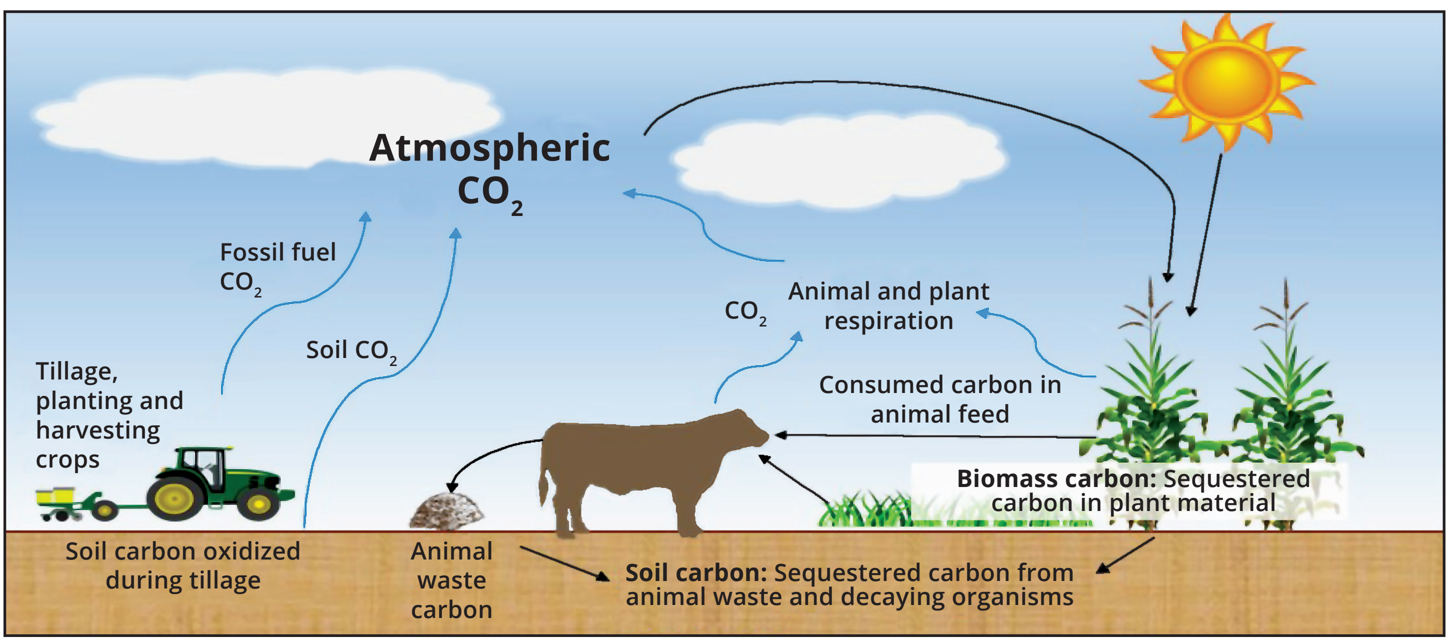


Figure 1. Carbon cycle demonstrating both additions to and removal of atmospheric carbon dioxide (CO_2)
Clip art courtesy of www.openclipart.org.

in the soil. Whenever soil is disturbed and exposed to the air, it releases stored carbon back into the atmosphere. Carbon is also released into the atmosphere from anthropogenic activities, such as burning fossil fuels (which are themselves reservoirs of carbon).

Many different agricultural production practices exist that can capitalize on carbon sequestration in both soil and biomass to reduce environmental impact. The goal of these methods is to modify current production practices in a way that enables the use of the natural carbon cycle to replenish carbon stores while reducing the amount of carbon in the atmosphere.[1] Restorative agricultural production practices have the potential to decrease atmospheric carbon and reverse some of the effects of climate change.[1,2] One example of a restorative practice is "no-till" crop production, where farmers do not turn over or till the soil (commonly done to reduce weed growth) in preparation for planting the next round of crops.[3] Some "no-till" cropping systems also incorporate cover crops, which involves planting a secondary crop that will not be harvested (such as turnips), but can be utilized for grazing beef cattle, controlling weed growth, reducing erosion, and enhancing soil organic matter.[2]

Beef cattle production can play an important role in furthering carbon sequestration by producing a nutritious food product for humans by utilizing grasslands that can store a large amount of carbon. Globally, if soil organic carbon in agricultural lands and grasslands could be increased 10% over the course of the 21st century, carbon dioxide concentrations in the atmosphere could be reduced by 110 ppm.[1] Grazing cattle and other ruminants on pasture and grasslands can preserve untilled land and reduce soil erosion (another environmental benefit) while producing human food and other products (e.g., leather).[2]

In the United States, pasture and grasslands represent 27% of the land area,[4] thus preventing the conversion of this land to tilled cropland and residential uses could prevent further increases in GHG concentrations. Additionally, establishing permanent pastures for grazing beef cattle on degraded croplands (lands that are currently tilled, but are of poor quality) can sequester carbon at rates comparable to forests.[2] Most beef cattle in the United States spend the majority of their lives on pastures and grasslands. For beef cattle finished in a feedlot, approximately 65-85% of their life will be spent grazing, and, for grass-finished beef cattle and beef cows, up to 100% of their life may be spent grazing. As a consequence, regardless of the beef production system, enhancing carbon sequestration through well-managed beef cattle grazing systems and improved feed production practices (e.g., no-till systems, using cover crops) can reduce the carbon footprint of beef and contribute to the reversal of global climate change.

***Bottom Line:* Carbon sequestration is the long-term storage of carbon from the atmosphere in soil and plants. There are many different techniques to achieve carbon sequestration, including reducing tillage of soil and establishing permanent grasslands. Beef cattle play an important role in increasing carbon sequestration through the production of human food from untilled pastures and grasslands, and the integration of cattle grazing into "no-till" cropping systems.**

Literature Cited

[1]Lal, R. 2011. Sequestering carbon in soils of agro-ecosystems. Food Policy. 36(Suppl. 1):S33-S39.

[2]Council for Agricultural Science and Technology (CAST). 2011. Carbon sequestration and greenhouse gas fluxes in agriculture: challenges and opportunities. Task Force Report No.142.

[3]Aziz, I., T. Mahmood, and K.R. Islam. 2013. Effect of long-term no-till and conventional tillage practices on soil quality. Soil Till. Res. 131: 28-35.

[4]Nickerson, C., R. Ebel, A. Borchers, and F. Carriazo. 2011. Major uses of land in the United States, 2007. Economic Information Bulletin Number 69. USDA/ERS, Washington, DC

For more information, contact:

National Cattlemen's Beef Association
Contractor to the Beef Checkoff Program
9110 East Nichols Avenue
Centennial, CO 80112
303.694.0305

BEEF FACTS: SUSTAINABILITY

BEEF RESEARCH

Fact Sheet 5 in the Series: Tough Questions about Beef Sustainability

Do growth promotants reduce environmental impact?

Ashley Broocks, Megan Rolf and Sara Place

Increasing the efficiency of beef production is one way to reduce environmental impact. Growth promotants (GP) play an important role in increasing the efficiency of beef production through increasing the conversion of the feed cattle eat into beef. While some types of growth promotants can be utilized earlier in an animal's life, they are primarily utilized during the finishing phase, which is approximately the last 120-140 days before the animal is harvested. Three commonly used types of GPs in beef production are: growth implants, ionophores, and β-adrenergic agonists (βAA). Beef production systems that use GP technologies are typically referred to as "conventional," whereas production systems that never use any of the three technologies are usually referred to as "natural" beef production systems.

Growth implants are small capsules that are placed in the backside of the animal's ear, which release a small amount of either natural or synthetic hormones over time. They work in conjunction with the animal's natural hormones to increase growth and typically consist of synthetic estrogen, testosterone, or progesterone.

Ionophores are feed additives used to alter rumen bacterial fermentation, allowing for improved feed efficiency and decreased methane (a greenhouse gas, or GHG) emissions. Ionophores can be utilized in any phase of the beef animal's life cycle (e.g., when they are raised on grass or in the feedlot during finishing), and can often be found in protein or energy supplements provided to beef cows to help them meet their nutrient requirements while grazing low-quality grasses.

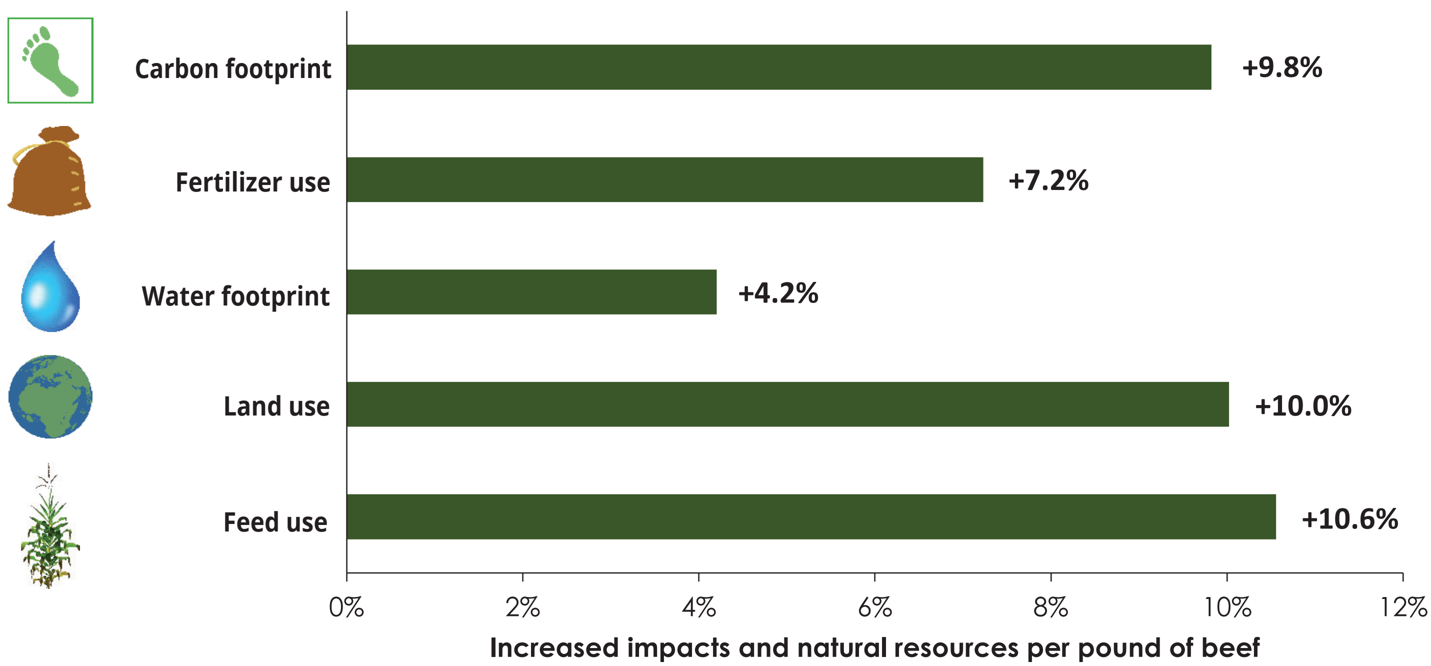


Figure 1. Increase in environmental impacts per unit of beef if no growth promoting technologies were used in U.S. beef production systems.

BeefResearch.org
303.694.0305
BEEF
Funded by the Beef Checkoff.

Finally, βAA are also a feed additive, but are restricted to the final 20-40 days of finishing. β-adrenergic agonists increase lean muscle mass while decreasing fat deposition, which means for every pound of body weight an animal gains when fed βAA, a higher proportion of the body weight gain will be protein than a similar animal not fed βAA[1]. Each GP works individually to improve feed efficiency but combining the three GPs can dramatically improve production efficiency, especially during the finishing phase, and can decrease GHG emissions per pound of body weight gain by 28% when compared to beef production systems not using GPs[2].

While ionophores can directly reduce methane emissions produced by individual beef cattle, in general, GPs reduce both GHG emissions produced and natural resources required per unit of beef (**Figure 1**) by decreasing the length of time required for an individual animal to reach harvest and the number of animals required to produce a given amount of beef.[2,3] For example, research has shown that in beef production systems using GP technologies, each animal will produce enough beef to feed approximately 1.66 more U.S. citizens as compared to animals in beef production systems that do not use those technologies (**Figure 2**).[4] Research utilizing both live animals[1,2,4] and computer models[3,5] has consistently shown a decrease in the environmental impact of beef production with the use of GP technologies. Some consumers prefer to purchase beef not produced in systems that use GP technologies (i.e., "natural" beef), which is a recognized food choice; however, there are negative environmental sustainability consequences for not using GP technologies in U.S. beef production.

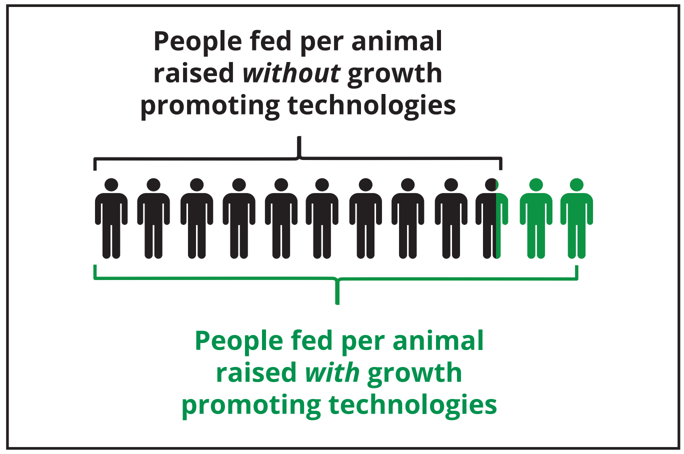


Figure 2. People fed per beef animal for one year per animal for beef production systems that use no growth promoting technology (black) as compared to beef systems that use growth promoting technology (black plus green).

Bottom Line: **Growth promoting technologies can reduce the environmental impact of beef production by decreasing the number of cattle required to produce a given amount of beef. Additionally, growth promoting technologies allow farmers and ranchers to feed more U.S. citizens with each beef animal that is raised under their care.**

Literature Cited

[1]Stackhouse-Lawson, K.R., M.S. Calvo, S.E. Place, T.L. Armitage, Y. Pan, Y. Zhao, and F.M. Mitloehner. 2013. Growth promoting technologies reduce greenhouse gas, alcohol, and ammonia emissions from feedlot cattle. J. Anim. Sci. 91:5438-5447.

[2]Cooprider, K.L., F.M. Mitloehner, T.R. Famula, E. Kebreab, Y. Zhao, and A.L. Van Eenennaam. 2011. Feedlot efficiency implications on greenhouse gas emissions and sustainability. J. Anim. Sci. 89:2643-2656.

[3]Capper, J.L. and D.J. Hayes. 2012. The environmental and economic impact of removing growth-enhancing technologies from U.S. beef production. J. Anim. Sci. 90:3527-3537.

[4]Maxwell, C.L., C.R. Krehbiel, B.K. Wilson, B.T. Johnson, B.C. Bernhard, C.F.O'Neill, D.L. VanOverbeke, G.G. Mafi, D.L. Step, and C.J. Richards. Effects of beef production system on animal performance and carcass characteristics. 2014. J. Anim. Sci. 92:5727-5738.

[5]Battagliese, T., J. Andrade, I. Schulze, B. Uhlman, C. Barcan. 2013. More sustainable beef optimization project: Phase 1 final report. BASF Corporation. Florham Park, NJ.

For more information, contact:

National Cattlemen's Beef Association
Contractor to the Beef Checkoff Program
9110 East Nichols Avenue
Centennial, CO 80112
303.694.0305

BEEF FACTS: SUSTAINABILITY

BEEF RESEARCH

Fact Sheet 6 in the Series: Tough Questions about Beef Sustainability

Does grass-finished beef leave a lower carbon footprint than grain-finished beef?

Ashley Broocks, Emily Andreini, Megan Rolf and Sara Place

Even though cattle live the majority of their lives on pasture, the type of finishing system does impact the carbon footprint of beef. The carbon footprint for beef is all the greenhouse gas emissions yielded during the production of beef divided by the total amount of beef produced by the system. Beef production consists of three main phases: cow-calf, stocker/backgrounding, and finishing (**Figure 1**). The first phase of the animal's life is spent nursing and grazing on pasture along with its mother. After calves are weaned, they typically spend additional time grazing crop residue that remains after harvesting grain or grazing forage pastures and grasslands. During this time, known as the stocker or backgrounding phase, they gain additional weight as they prepare to enter the finishing phase. The finishing phase is the final stage before cattle are sent for harvest. Cattle entering the finishing phase are typically 12 to 16 months old, and remain in this phase until they have achieved a level of marbling that will provide a positive eating experience for consumers. The main difference in carbon footprints between grass- and grain-finished beef occurs as a result of the time spent in the finishing phase, the type of feed consumed, and the ending body weight of the cattle in the finishing phase.

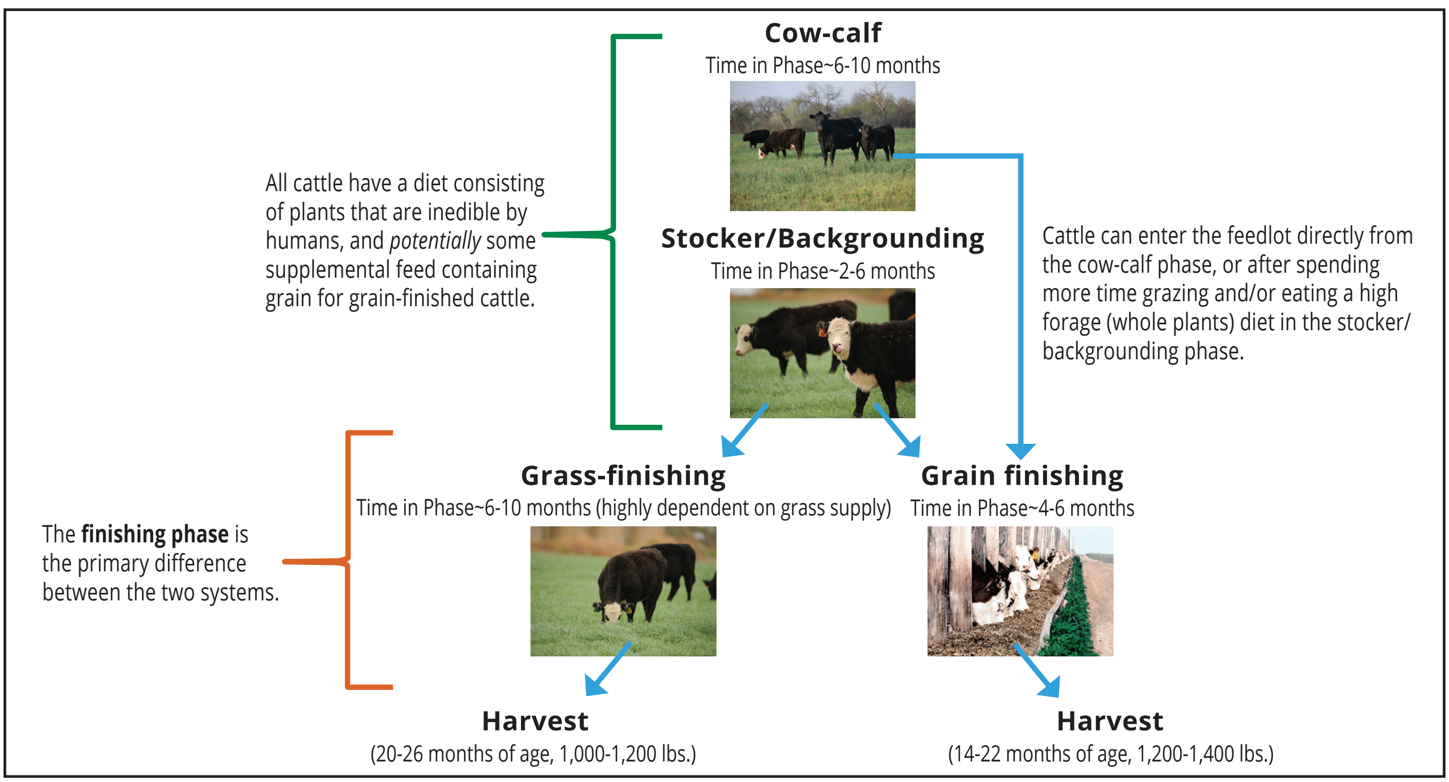


Figure 1. Beef cattle life cycle in the United States for grass-finished and grain-finished beef.

Cattle entering the feedlot for finishing eat a diet that contains corn along with by-products (such as distillers grains leftover after ethanol production), vitamins and minerals, and forage or roughage (such as hay). Grain-finished cattle remain in the feedlot for approximately four to six months and are sent for harvesting at 14 to 22 months of age. Grain-finished cattle reach market weight faster than grass-finished[1,2] because the diet the animals receive is higher in energy, which results in more efficient weight gain. In contrast, grass-finished cattle gain at a slower rate due to the forage-based diet they eat and typically go to harvest at 20-26 months of age and at a lower weight than grain-finished animals. Grass-finished cattle may finish either faster or slower than this age range depending on the forage and grass resources available to the beef producer (e.g., the growing season is shorter in northern U.S. states, which may shorten the finishing period and lead to lighter weights at harvest). The difference in harvest weights translates into different numbers of U.S. citizens that could be fed per animal (**Table 1**). Utilizing forage as the primary source of feed also contributes to an increased carbon footprint for grass-finished beef,[2] because high forage diets (e.g., grass) produce more methane emissions from the animal's digestive tract than higher-energy, grain-based diets. The combination of consuming a higher energy, lower forage diet, shorter time spent on feed during finishing, and heavier carcass weights translate into a 18.5 to 67.5% lower carbon footprint for grain-finished beef as compared to grass-finished beef.[1,2]

Even though grass-finished beef has a higher carbon footprint, it does have some sustainability advantages. Grass-finished animals utilize plants that are inedible by humans as the primary source of energy and nutrients for their entire lifetimes. In contrast, 82% of feed intake per unit of carcass weight for conventional animals occurs from grazing forage, pasture or rangeland.[5] Beef cattle can utilize forage grown on land not suitable for crop production, and thus produce human edible food from a resource that could not otherwise be used to produce food. Additionally, grasslands and pastures can sequester carbon dioxide from the atmosphere, which can help to mitigate global climate change. Research has shown an advantage for grass-finished beef production over grain-finished beef production when expressing feed conversion as human edible energy returned per unit of human edible energy consumed by the cattle.[2,6]

Accounting for carbon sequestration of grass-finished beef that is finished on pastures could lower the carbon footprint of grass-finished beef by 42%.[2] Ultimately, tradeoffs exist between the two beef production systems; however, beef producers using either system can sustainably meet consumer demand for beef by utilizing the resources they have in their part of the country.

Bottom Line: **Tradeoffs occur in different aspects of sustainability when comparing grain-finished and grass-finished beef production systems. Grain-finished beef has a lower carbon footprint than grass-finished beef due to more efficient utilization of feed in the finishing phase, fewer days on feed, and greater amount of beef produced per animal. However, grass-finished beef contributes to sustainable beef production by utilizing forage resources during finishing to produce food from plants that are inedible by humans.**

Table 1. U.S. citizens fed for one year per animal for grass-finished and grain-finished beef.

Finishing system	Harvest live weight, lbs.	Dressing %	Carcass Weight per animal, lbs.	U.S. citizens fed per animal*
Grass-finished	1,100	58%	638	8.0
Grain-finished	1,300	64%	832	10.4

*Assuming 80.1 lbs. of carcass weight availability per capita in 2013[4]

Literature Cited

[1]Capper, J.L. 2012. Is the grass always greener? Comparing the environmental impact of conventional, natural and grass-fed beef production systems. Animals. 2:127-143.

[2]Pelletier, N., R. Pirog, and R. Rasmussen. 2010. Comparative life cycle environmental impacts of three beef production strategies in the Upper Midwestern United States. Agric. Sys. 103:380-389.

[3]IPCC. 2013. Climate change 2013: The physical science basis. Contribution of working group I to the fifth assessment report of the IPCC. Cambridge University Press. Cambridge, UK.

[4]USDA. 2014. Food Availability (Per Capita) Data System. Available from: http://www.ers.usda.gov/data-products/food-availability-%28per-capita%29-data-system/readings.aspx

[5]Rotz, C.A. S. Asem-Hiablie, J. Dillion, and H. Bonifacio. 2015. Cradle-to-farm gate environmental footprints of beef cattle production in Kansas, Oklahoma, and Texas. J. Anim. Sci. 93:2509-2519.

[6]Wilkinson, J.M. 2011. Re-defining efficiency of feed use by livestock. Animal. 5:1014-1022.

For more information, contact:

National Cattlemen's Beef Association
Contractor to the Beef Checkoff Program
9110 East Nichols Avenue
Centennial, CO 80112
303.694.0305

BEEF FACTS: SUSTAINABILITY

BEEF RESEARCH

Fact Sheet 7 in the Series: Tough Questions about Beef Sustainability

If we fed corn to humans instead of cattle, would land use be more sustainable?

Ashley Broocks, Megan Rolf and Sara Place
Oklahoma State University

Corn grain is used in beef cattle production because of its advantages in improving the efficiency of growth.[1] However, corn grain typically does not make up a large portion of cattle diets until the end of their life cycle in a period called "finishing" when cattle are often housed in a feedlot (**Figure 1**). The majority of a beef animal's life in the U.S., regardless of whether they are grain- or grass-finished, will be spent on grass consuming forages (whole plants). Depending on the region of the country and the prices and availability of different feeds, corn grain may make up 50-85% of a grain-finished animal's diet during the finishing phase. The other 15-50% of the animal's diet will be made up of forages or roughages (e.g., hay), by-products (e.g., distiller's grains), and minerals and vitamins. In addition to improving growth efficiency, corn grain is fed to cattle in the finishing phase because it increases carcass quality grades by increasing fat deposition (especially intramuscular or "taste" fat), which results in a more desirable product for consumers. Cattle on grass, including grass-finished beef, can also require supplementation of energy or protein-dense feeds that may contain corn grain in order to meet their nutrient requirements when the nutritional quality of the grass is low.

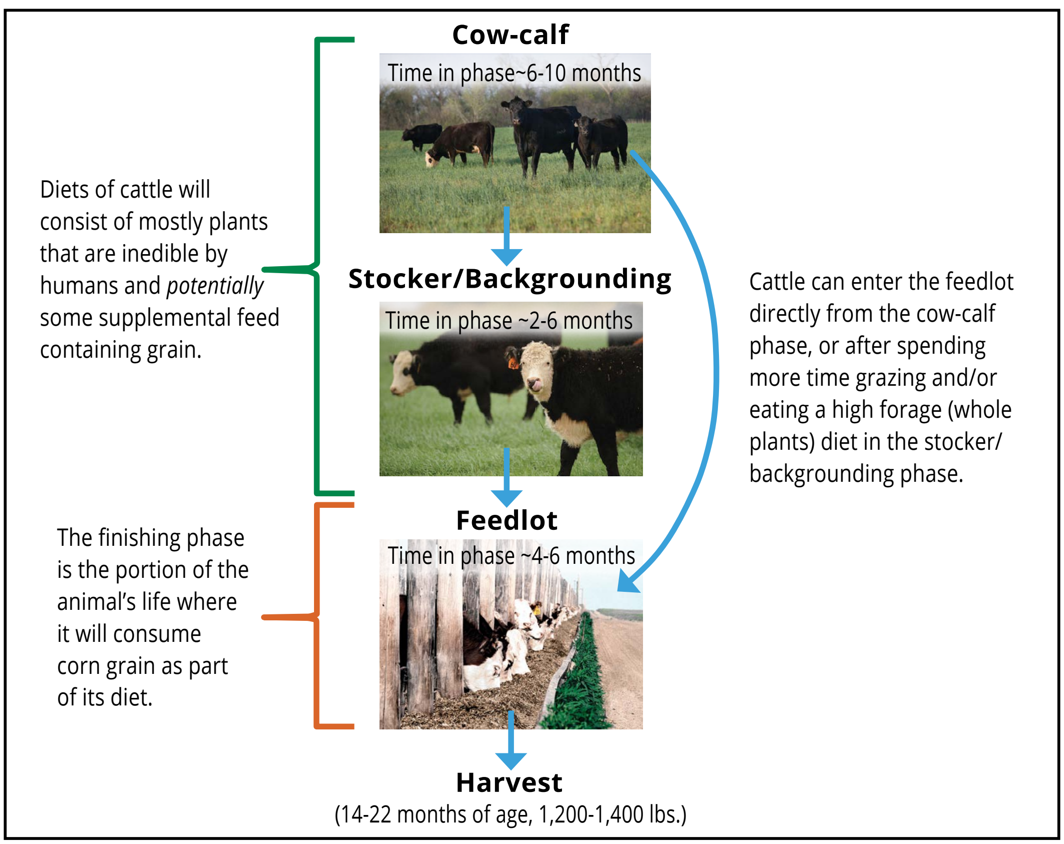


Figure 1. Typical life cycle of beef cattle in the United States.

While the diet provided to finishing cattle in feedlots relies on some human-edible inputs (i.e., corn grain), the forages and by-products fed to cattle throughout their lives are largely inedible to humans.[2] For example, once the entire lifetime feed intake of cattle is accounted for (meaning all the feed they consume from birth to harvest), corn only accounts for approximately 7% of the animal's diet.[3] The other 93% of the animal's lifetime diet will consist largely of feed that is inedible to humans, and thus not in direct competition with the human food supply. Unlike humans, cattle can efficiently digest fiber and convert human-inedible feeds into nutritious, human-edible foods.

One of the major human-inedible by-products fed to beef cattle is distiller's grains, which is a by-product of alcohol production from corn (either for fuel or human consumption). The amount of distiller's grains fed to beef cattle has increased in recent years as the production of fuel from corn has increased. As **Table 1** demonstrates, the proportion of corn used for fuel production in the United States relative to animal feed has dramatically increased in recent years. In contrast, the percentage of corn used for human food has been relatively unchanged.

Table 1. Domestic uses of U.S. corn grain as a percentage of total domestic use in recent decades.

Year	Human food, seed, and industrial uses	Alcohol for fuel use (Ethanol)	Animal feed* and residual use
1980	12.8%	0.7%	86.5%
1990	18%	6%	76%
2000	17%	8%	75%
2010	13%	45%	43%
2015	12%	44%	45%

*Animal feed includes all types of domestic animals in the U.S., not just beef cattle (e.g., dairy cattle, swine, chickens, turkeys, horses, etc.). Data from USDA-ERS, 2015.[4]

Using recent data as a guide, one can predict that land used to grow corn for animal feed would likely be shifted to grow corn for fuel use if less corn grain were fed to beef cattle, and would not shift towards human consumption. Altering the lifetime consumption of corn grain by cattle, which is only approximately 7% of an average animal's total lifetime feed intake,[3] would likely have a very minor impact on the sustainability of land use.

Corn production, like all crop production, does have an environmental sustainability impact. Thus, reducing corn's environmental impact through better production practices and using new technologies would improve land use sustainability regardless of the corn's end use (human food, animal feed, or fuel). Such improvements include no-till or conservation tillage practices to reduce soil erosion and increase soil organic carbon,[4] winter cover crops to reduce nutrient run-off,[5] and precision agriculture techniques to apply fertilizer at variable rates across a field to minimize nutrient emissions to the environment while improving corn yields. Indeed, past improvements in crop yields, including corn, have contributed to reducing environmental impacts per unit of beef 12% from 1970 to 2011.[7]

Bottom Line: **Regardless of the type of beef production system, the majority of beef cattle's nutrient requirements over a lifetime are met with human inedible feeds. Only 7% of beef cattle's lifetime feed intake is corn grain. Improvements in corn production efficiency (minimizing environmental impacts relative to corn yield) will help improve land use sustainability regardless if corn is used for human consumption, beef cattle consumption, or fuel use.**

Literature Cited

[1]Bradford, G.E. 1999. Contributions of animal agriculture to meeting global human food demand. Livest. Production Sci. 59:95-112.

[2]Council for Agricultural Science and Technology (CAST). 1999. Animal agriculture and global food supply. Task Force Report. No. 135.

[3]Capper, J.L., L. Berger, M.M. Brashears, and H.H. Jensen. 2013. Animal feed versus human food: Challenges and opportunities in sustainable animal agriculture toward 2050. CAST. 53:1-16.

[4]USDA-ERS. 2015. Corn – Background. Accessed December 10, 2015 from http://www.ers.usda.gov/topics/crops/corn/background.aspx.

[5]Kumar, S., A. Kadono, R. Lal and W. Dick. 2012. Long-term no-till impacts on organic carbon and properties of two contrasting soils and corn yields in Ohio. Soil Sci. Soc. Am. J. 76(5):1798-1809.

[6]Dabney, S.M., J.A. Delgado, and D.W. Reeves. 2001. Using winter cover crops to improve soil and water quality. Commun. Soil Sci. Plan.32(7-8):1221-1250.

[7]Battagliese, T., J. Andrade, I. Schulze, B. Uhlman, C. Barcan. 2013. More sustainable beef optimization project: Phase 1 final report. BASF Corporation. Florham Park, NJ.

For more information, contact:

National Cattlemen's Beef Association
Contractor to the Beef Checkoff Program
9110 East Nichols Avenue
Centennial, CO 80112
303.694.0305

BEEF FACTS: SUSTAINABILITY

BEEF RESEARCH

Fact Sheet 8 in the Series: Tough Questions about Beef Sustainability

Is local beef more sustainable?

Ashley Broocks, Megan Rolf and Sara Place
Oklahoma State University

Consumer interest in locally produced food has increased dramatically over the past few decades. While there is no single formal definition of local food, the term local food commonly means food grown or raised between 100-400 miles of where it is purchased, or simply food produced within the same state.[1] However, local can mean different things to different people, especially if we consider the size of different states (take Rhode Island vs. Texas as an example). It is important to note that local does not imply one production system was used over another, it simply means that the product was produced within a certain distance of where it is being sold.

From an environmental sustainability perspective, the primary difference between local and non-local products is the type of transportation used in moving post-harvest beef from processors to consumers, as shown in **Figure 1**. Measuring and comparing GHG emissions

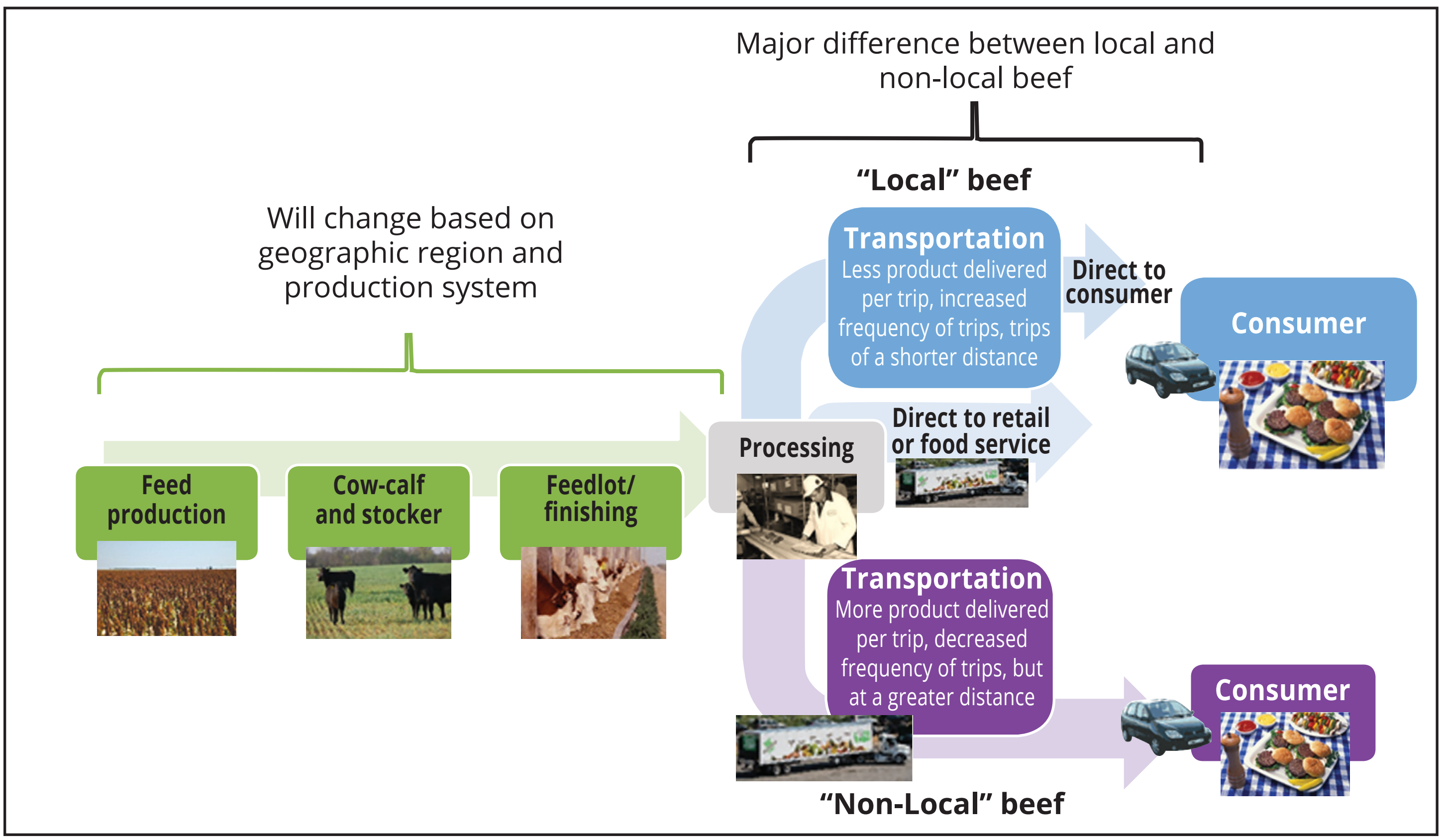


Figure 1. Major differences in the beef value chain between local and non-local beef are primarily due to transportation.*
*Photos courtesy of Oklahoma State University, USDA-ARS, USDA-NRCS, and openclipart.org

due to transportation of beef from local and national locations is difficult because mode of transportation, load sizes, fuel type, distance to market, and frequency of trips are rarely similar.[1] However, approximately 80% of GHG emissions occur in the beef value chain before the animal is harvested[2] and approximately 1-3% of GHG emissions occur due to transportation of beef to the consumer.[3,4] Local food, including beef, is either marketed directly to consumers, or marketed to foodservice (e.g., restaurants) and retailers and then purchased by consumers. The appeal of purchasing local foods is often associated with perceived reductions of greenhouse gases (GHGs) because the product travels shorter distances from the producer to the consumer, thereby reducing what is known as “food miles.” However, there is a tradeoff between the increased frequency of trips and smaller load sizes versus the distance traveled per trip in local beef systems as compared to the mainstream beef transportation system. This is because more beef moved per trip will translate into lower fossil fuel energy use and lower GHG emissions per unit of beef transported.[1] Consequently, even if transportation distances were cut significantly for local beef, the impacts on GHG emissions are likely minimal.

While the environmental benefits of local beef (strictly considering transportation differences) may be minimal, many consumers that purchase local beef and other food products do so for social reasons, such as wanting to support their local economy and wanting to know where their food comes from.[5] To consumers that weigh those factors heavily in their purchasing decisions, local beef may be viewed as their most desirable choice. However, the effects of purchasing local food, including beef, on the local economy are not clear-cut nor are any economic benefits evenly distributed across communities (e.g., if a consumer shifts from purchasing at a retailer to a farmers market, the local owner(s) and operator(s) of the retailer will likely be negatively impacted).[1,6]

Additionally, it is unlikely that all U.S. consumers will have access to local beef if it is defined as within 100-400 miles of where one lives, due to land use constraints. For example, in highly populous cities, it would be unlikely that the land immediately surrounding the city would be able to support enough beef production to make local beef accessible to all consumers in that city. In more rural areas, rising land costs due to competition with crop production and expansion of residential housing may limit the ability to produce enough local beef to feed the population.

Regardless of where beef is produced, beef producers and researchers are continuously working toward improving the sustainability of beef production. As more of the environmental impact of beef production can be attributed to the raising of cattle and the feed fed to the cattle, focusing on improving the production efficiency of beef will have a far greater impact on environmental sustainability than reducing food miles. Sustainable beef production is not limited to a single production system, so all beef production systems (e.g., local, non-local, organic, conventional, grass-finished, grain-finished) can be sustainable if they are committed to constant improvement in all aspects of sustainability, including environmental impact, societal acceptance, and economic viability of production systems.[2]

Bottom Line: **The term “local” simply reflects the distance a product has been transported before being marketed and does not necessarily reflect differences in production practices or sustainability. The environmental sustainability benefit of purchasing local beef products are likely minimal as, 1) transportation accounts for only 1-3% of GHG emissions per unit of beef, and 2) local beef products can decrease transportation distance, but often at the expense of increased frequency of shorter distance trips due to smaller beef delivery sizes; therefore, GHG emissions from the burning of fossil fuels per unit of beef may not be greatly impacted.**

Literature Cited

[1]Martinez, S., M. Hand, M. Da Pra, S. Pollack, K. Ralston, T. Smith, S. Vogel, S. Clark, L. Lohr, S. Low, & C. Newman. 2010. Local food systems: concepts, impacts, and issues. USDA ERS 97: 1-87.

[2]Battagliese, T., J. Andrade, I. Schulze, B. Uhlman, C. Barcan. 2013. More sustainable beef optimization project: Phase 1 final report. BASF Corporation. Florham Park, NJ.

[3]Weber, C. and H.S. Matthews. 2008. Food miles and the relative climate impacts of food choices in the United States. Environ. Sci. Tech. 42: 3508-3513.

[4]Sanders, K.T., and M.E. Webber. 2014. A comparative analysis of the greenhouse gas emissions intensity of wheat and beef in the United States. Environ. Res. Lett. 9: 1-9.

[5]Brain, R. 2012. The local food movement: Definitions, benefits & resources. Utah State University Extension. Available at: https://extension.usu.edu/files/publications/publication/Sustainability_2012-09pr.pdf Accessed December 18, 2015.

[6]Born, B. and M. Purcell. 2006. Avoiding the local trap: Scale and food systems in planning research. J. Plan. Educ. Res. 26:195-207.

For more information, contact:

National Cattlemen's Beef Association
Contractor to the Beef Checkoff Program
9110 East Nichols Avenue
Centennial, CO 80112
303.694.0305

BEEF FACTS: SUSTAINABILITY

BEEF RESEARCH

Fact Sheet 9 in the Series: Tough Questions about Beef Sustainability

Can different LCA studies be compared?

Greg Thoma, Ph.D.
University of Arkansas

Life Cycle Assessment (LCA) is a well-established tool that was first developed in the 1960s to evaluate potential environmental impacts arising from the production and consumption of goods and services. LCA procedures are defined in the 14040 series of International Organization for Standardization standards (ISO). The main standard, 14044, defines four iterative stages (indicated by the bidirectional arrows in **Figure 1**) in performance of a LCA. These are the goal and scope definition, life cycle inventory data collection, life cycle impact assessment, and interpretation.[1] In defining the goal and scope of a study, a LCA practitioner must specify the reasons for conducting the study and the intended audience. Reasons for conducting a LCA include:

- Hotspot analysis to identify stages or activities in a supply chain, which contribute significantly to environmental impacts;
- Support for internal decisions to identify improvement opportunities or establish a baseline or benchmark;
- Direct comparison of products (either for procurement or marketing), which may or may not be disclosed to the public.

Defining the goal and scope requires specifying the functional unit, system boundaries, impact assessment categories, and cut-off criteria. Specifying the functional unit of the study is a crucial aspect of the goal and scope. The definition of the functional unit should answer the question: how much of the product is required to provide what function for a specific period of time? System boundaries should include all life cycle stages from extraction of raw materials to the final disposition of the product and its packaging at the end of its life. This will enable identification of burden shifting along the supply chain. The standard also specifies that a full complement of impact categories

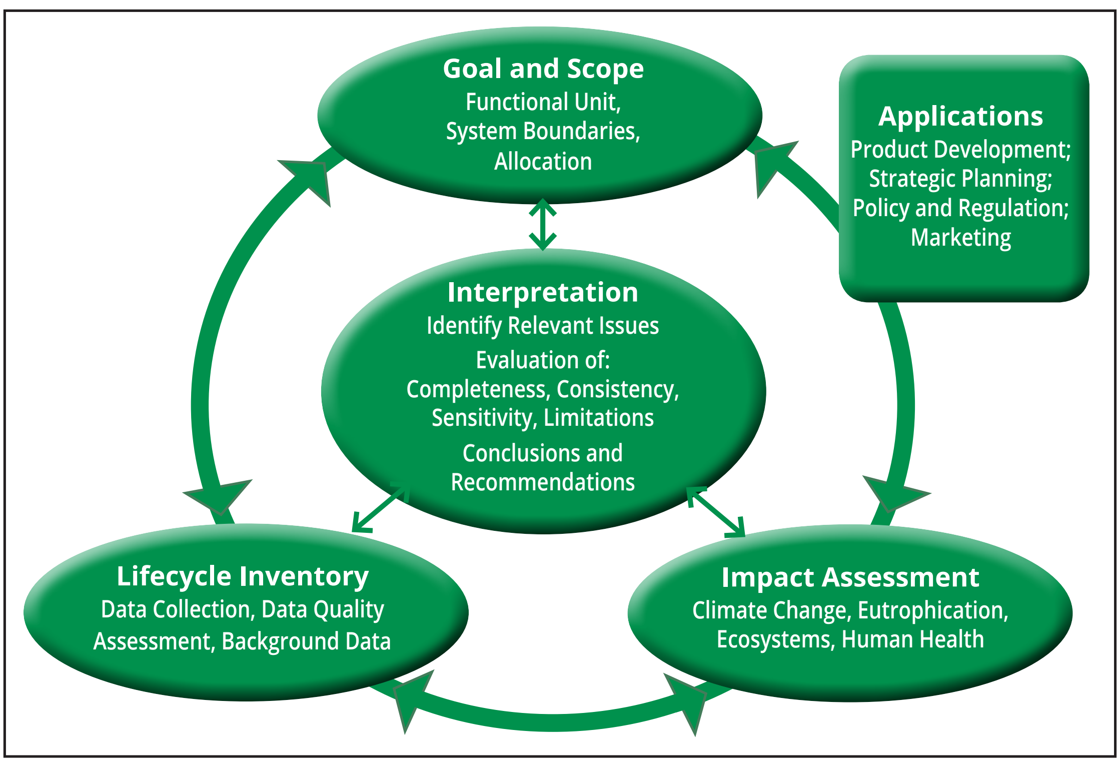


Figure 1. Stages of a lifecycle assessment study.

be considered for the express purpose of enabling the identification of trade-offs among impacts, in particular for comparative studies.

The ISO standards provide broad guidance on performing a LCA and also rules for comparative studies. ISO and the ILCD (*General Guide for LCA — Detailed Guidance* published by the European Union) handbook mandate, for both assertive and non-assertive comparative studies, application of the same functional unit, system boundary, and allocation procedures; to have same data quality and completeness/cut-off (in%) for mass and energy requirements; and to apply the same Life Cycle Impact Asessment (LCIA) methods.[1,2] These criteria are equally important and should be fully evaluated when comparing LCAs from different authors.

As an example, if 2 studies of exterior paint are to be compared, and they have reported functional units of 1 gallon of paint, it may not be possible to make a direct comparison. The primary function of paint may be to protect exterior surfaces, and if the paints' lifetimes are different, then a volumetric functional unit will not capture this difference in function, as one paint may require 2 applications separated by a period of years to achieve the same protection as the other paint. Stated another way: comparison of a specific volume of a high-quality to a low-quality paint may not satisfy the requirement of comparable functional units.

Because many reasons exist to perform a LCA and different ways exist to define function, as well as choices to include or exclude certain aspects (such as infrastructure), our ability to make straight forward, direct comparisons between LCAs performed by different research groups is compromised. Despite the challenges of comparing different LCAs, a need to make such comparisons frequently exists. Recently, meta-analysis of LCA[3,4] has become more common. Meta-analysis is a harmonization process to adjust parameters from different LCAs to ensure methodological consistency to enable comparison. The purpose of the meta-analysis is to provide decision-makers with a more robust understanding of conflicting studies in the literature, or more simply, to compare results of two studies of similar products with the same function produced with different technologies or from different geographic regions. For example, the National Renewable Energy Laboratory has performed the Lifecycle Assessment Harmonization Project,* which provides additional more detailed guidance on the process undertaken for electricity generation. Additionally, comparison can be strengthened by assessing conclusions and recommendations from different studies.

*http://www.nrel.gov/analysis/sustain_lca_method.html

Based on the preceding description of the stages of a LCA, it is clear what kinds of information are needed, at a minimum, to ensure comparability of two studies: corresponding functional units and system boundaries. In food and agriculture LCAs, numerous functional units have been used. Some common choices include: live or as-harvested weight, at the farm gate for livestock and crops respectively. These may be expressed on a per animal basis or per kg basis. If sufficient information is not provided in the study to allow conversion of the units to correspond, then comparison will not be possible. The guidelines developed by the U.N. Food and Agriculture Organization's Livestock Environmental Assessment and Performance (LEAP) Partnership provide information on specification of functional units with sufficient detail to enable these types of conversion.[5,6] An example of a well characterized functional unit is from the Phase I: More Sustainable Beef Optimization Project.[7] In this assessment, the loss in the beef supply chain is described as leading to the chosen functional unit of lean meat consumed (**Table 1**), enabling other users to compare results they may have for the farm gate production.

Table 1. Dressing weight and value chain losses.

Dressing	59%
Harvesting (fat, bone and shrink)	33%
Retail phase (fat, bone, shrink)	4%
Consumer phase (cooking loss, spoilage, plate waste)	20%
Total loss from live weight at farm gate	70%

For crop production, the moisture content should (but may not) be specified. Other possible functional units for livestock include carcass weight or edible cuts at the packer plant gate. Some studies will report a functional unit of carcass weight at the farm gate – this choice represents two errors which should be corrected. The first is that valuable co-products are produced (non-edible offal, etc) in processing and an allocation to these co-products may be missing if carcass weight is used at the farm gate; the second error is that energy and other resources expended in the processing stage, and burdens associated with these activities, are excluded at the farm gate. Additional considerations regarding the harmonization of system boundaries include activities which may be excluded in one study or another. In particular, it is common in many studies - but not all - to exclude capital goods (infrastructure).

After harmonization of the functional unit and system boundaries, attention must be given to impact methods used in the studies. Many impact assessment frameworks are available, and each adheres to the ISO standard requirement of a direct causal link between emission and impact. However, various methods can use different estimation techniques even for similar categories. Therefore, it is critically important that the impact methods used in the studies being compared are the same – unless only a qualitative directional comparison is required. Even for evaluation of climate change, which is likely the most commonly reported impact category, care must be taken to ensure that the same global warming potentials (GWP) were used in the studies being compared. The 100-year GWP has changed in the past 20 years; for example, the 100 year GWP for methane was 21 (1996); 25 (2006) and is currently 28 (2013).

Bottom Line: **LCAs can be compared; however, significant care should be exercised in conducting the comparison or inappropriate conclusions may be reached.**

Literature Cited

[1]ISO. 2006. ISO 14044:2006 Environmental management — Life cycle assessment — Requirements and guidelines. 2006.

[2]JRC. 2010. ILCD Handbook: General guide for Life Cycle Assessment - Detailed guidance.

[3]Lifset, R. 2012. Toward Meta-Analysis in Life Cycle Assessment. J. Ind. Ecol. 16:S1–S2.

[4]Rocha, M. H., R. S. Capaz, E. E. S. Lora, L. A. H. Nogueira, M. M. V. Leme, M. L. G. Renó, and O. A. del Olmo. 2014. Life cycle assessment (LCA) for biofuels in Brazilian conditions: A meta-analysis. Renew. Sustain. Energy Rev. 37:435–459.

[5]LEAP. 2015a. Environmental performance of animal feeds supply chains: Guidelines for assessment. Rome, Italy.

[6]LEAP. 2015b. Greenhouse gas emissions and fossil energy demand from poultry supply chains: Guidelines for asssessment. Rome, Italy.

[7]Battagliese, T., J. Andrade, I. Schulze, B. Uhlman, and C. Barcan. 2013. More Sustainable Beef Optimization Project: Phase 1 Final Report June 2013.

For more information, contact:

National Cattlemen's Beef Association
Contractor to the Beef Checkoff Program
9110 East Nichols Avenue
Centennial, CO 80112
303.694.0305

Fact Sheet 10 in the Series: Tough Questions about Beef Sustainability

How do you know if you are looking at a comprehensive and high-quality life cycle assessment study?

Greg Thoma, Ph.D.
University of Arkansas

There is no single established approach for determining whether or not a life cycle assessment (LCA) is of high quality. This is partly because a LCA can be conducted for numerous reasons with different levels of rigor required for different goals. For example, a LCA intended to identify hotspots in a supply chain may not require exceedingly high data quality, whereas an assessment which is making a direct comparison of two products, for example in a green procurement situation, may need greater data accuracy and uniform data quality for both systems to support the decision. Nevertheless, international standards provide a minimum set of criteria against which the quality of a LCA study should be assessed and include guidance on the critical review required for different applications (ISO 14044:2006, 2006). If the LCA received a critical review, the results should be more reliable. Thus, aspects of the study that a peer reviewer would typically evaluate are also relevant in assessing the quality of any study. The main issues to look for in a LCA study is compliance with the ISO standards. To be defined as a comprehensive LCA, two hallmarks are associated with the goal and scope. First, the study should be a cradle-to-grave assessment, accounting for all extractions from nature required for producing the good or service, as well as accounting for the disposal and subsequent emissions associated with the final disposition of the product, including any packaging materials associated with its supply chain.

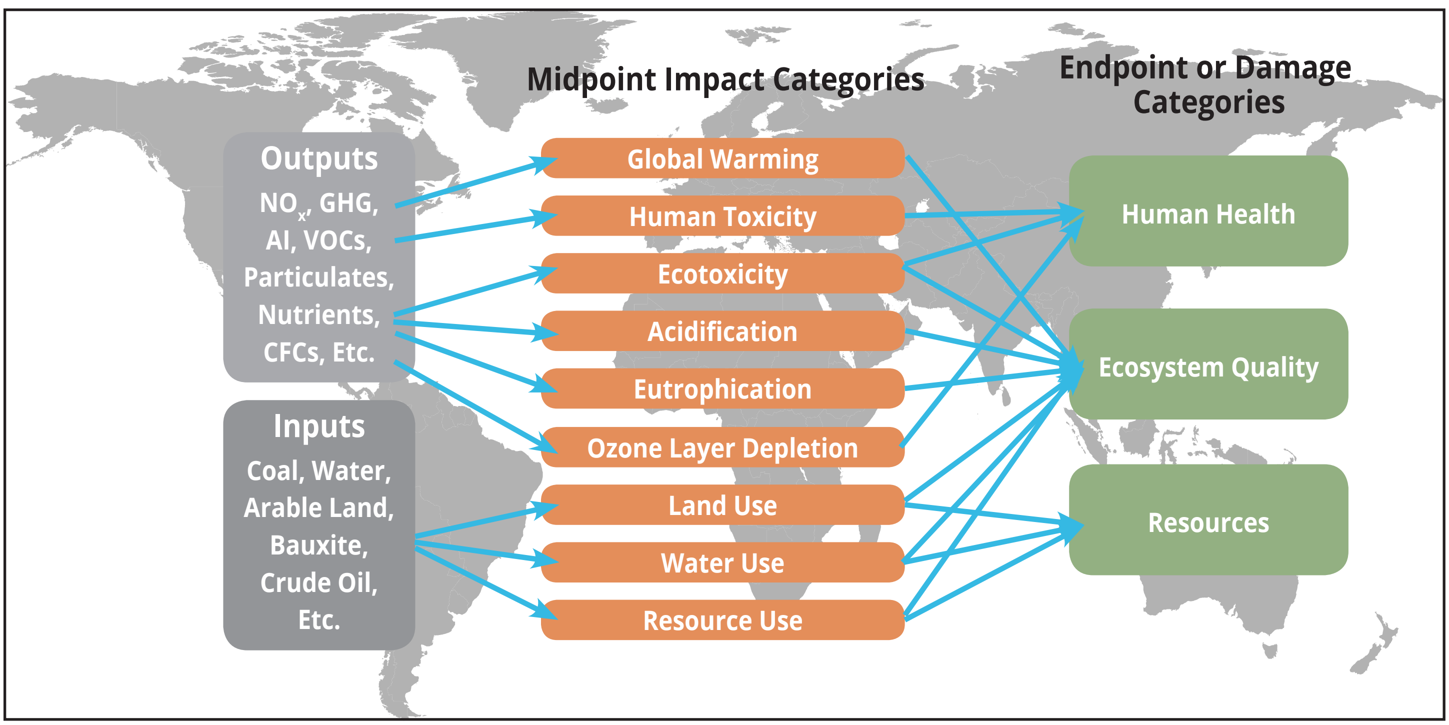


Figure 1. Impact World+ Methodology Framework (adapted from *www.impactworldplus.org*).

Second, a comprehensive LCA should include multiple impact categories which span major areas of production. These are generally considered to be human health, ecosystems, and resources (shown in **Figure 1**).[1] A life cycle impact assessment (LCIA) uses causal modeling to link resource use and emissions to midpoint categories, which are further combined to quantify impacts to endpoint categories or areas of production. One of the fundamental reasons for performing a LCA is to evaluate potential trade-offs among various impacts between stages of the supply chain. Therefore, studies which are focused on a single (i. e. footprints) or relatively few impact metrics are less comprehensive, because the ability to identify trade-offs is limited.

The most important characteristic of a high-quality LCA is transparency of the data and data sources. Transparency allows users and reviewers to evaluate, in detail, the foundational information which has been used to support the study conclusions. However, situations exist where complete transparency is not possible due to aggregation and use of confidential data or trade secrets. In these cases, an explanation of aggregation and reasons for non-transparent data should be provided. **Table 1** provides a sample of data sourcing with an appropriate note regarding confidential data coupled with a third party review.

Another characteristic is an analysis of the data quality which was achieved in the inventory phase as it relates to the ability of the authors to achieve the goal of the study. As mentioned previously, high-quality data, the absence of gaps in data for unit processes and the utilization of primary data rather than secondary data are all characteristics of higher-quality studies. The paper should provide a discussion of whether data gaps or the use of proxy or surrogate datasets may have impacted the study conclusions. The influence of modeling assumptions on the study results – such as choice of allocation procedures and decisions to include or exclude some aspects of the supply chain – should be evaluated through scenario analysis. High-quality studies will also include uncertainty analysis. Typically, Monte Carlo simulation is used to demonstrate the effects of data input uncertainty on LCA results, as shown in the example in **Table 2**. Finally, a section in the paper which discusses the study limitations with respect to conclusions also demonstrates quality in the results.

Bottom Line: **A comprehensive, high-quality life cycle assessment will be a cradle-to-grave assessment with multiple impact categories, spanning major areas of production and in compliance with ISO standards. In addition to these characteristics, the data used in the assessment should be transparent and a thorough analysis of the quality of the data as it pertains to the results should be performed. Studies which are focused on a single (i. e., footprints) or relatively few impact metrics are less comprehensive, because the ability to identify trade-offs is limited.**

Table 1. Eco-profile data sources (Battagliese et al., 2013)

Eco-Profile	Source, Year	Comments
Cardboard, recycled	Ecoinvent 2.2, 2010	Ecoinvent profile: corrugated board, recycling fiber, double wall, at plant/RER U
Paper		Ecoinvent profile: Paper, wood free, uncoated at non-integrated mill /RER U
Polypropylene	BASF, 1996	
Wood pallets		Ecoinvent profile: wood container and pallet manufacturing (USA Input Output Database)
BASF data sources are internal data, while others are external to BASF. Internal data is confidential to BASF; however, full disclosure was provided to NSF International for verification purposes.		

Table 2. Results of 1,000 Monte Carlo runs for uncertainty analysis of dry whey from cradle-to-customer per ton of dry whey solids (Kim et al., 2013).

Impact category	Unit	Mean	CV (%)	95% CI	
Climate change	kg CO_2e	1.21E+ 04	15.3	9.11E+03	1.61E+ 04
Cumulative energy demand	MJ	5.81E+ 04	28.5	4.09E+ 04	8.93E+ 04
Freshwater depletion	m^3	1.45E+ 03	16.2	1.05E+ 03	2.00E+ 03
Marine eutrophication	kg N eq.	3.73E+ 01	12.2	2.92E+ 01	4.77E+ 01
Photochemical oxidant formation	kg NMVOC	4.40E+ 01	12.9	3.33E+ 01	5.60E+ 01
Freshwater eutrophication	kg P eq.	7.52E+ 00	15.6	5.53E+ 00	1.01E+ 01
Ecosystems	Species/year	3.51E− 04	13.4	2.70E− 04	4.54E− 04
Human toxicity	CTUh	2.27E− 04	116	7.78E− 05	7.29E− 04
Ecotoxicity	CTUe	7.57E+ 04	14.9	5.69E+ 04	1.01E+ 05

Literature Cited

Battagliese, T., J. Andrade, I. Schulze, B. Uhlman, and C. Barcan. 2013. More Sustainable Beef Optimization Project: Phase 1 Final Report. June 2013.

ISO 14044:2006. 2006. Environmental management - Life cycle assessment — Requirements and guidelines. 2006.

Kim, D., G. Thoma, D. W. Nutter, F. Milani, R. Ulrich, and G. A. Norris. 2013. Life cycle assessment of cheese and whey production in the USA. Int. J. Life Cycle Assess. 18:1019–1035. Available from: http://link.springer.com/article/10.1007%2Fs11367-013-0553-9

For more information, contact:

National Cattlemen's Beef Association
Contractor to the Beef Checkoff Program
9110 East Nichols Avenue
Centennial, CO 80112
303.694.0305

BEEF FACTS: SUSTAINABILITY

BEEF RESEARCH

Fact Sheet 11 in the Series: Tough Questions about Beef Sustainability

How does animal health and welfare impact sustainability?

Ashley Broocks, Megan Rolf and Sara Place

While beef sustainability is often equated to environmental impact, it also encompasses economic viability and societal acceptance.[1] The dramatic increase in global population has resulted in the intensification (increased output per unit of input) of agriculture to meet growing food demand. Intensification in the beef industry has received scrutiny because some believe increased productivity comes at the expense of animal health and welfare.[2] In reality, ensuring that cattle have the highest standards of health and welfare is beneficial to both individual beef producers and the environmental, social, and economic sustainability of the entire beef industry.

Just like people experience stress, cattle can experience stressful events throughout their life cycle. If stressful events cause cattle to have decreased growth rates, feed conversion efficiency, reproductive rates, or lead to an increased susceptibility to illness, then all three components of beef sustainability (environmental, social, and economic) can be negatively impacted. The inter-relationship between animal welfare and sustainability is particularly well illustrated by the nexus between environmental quality and animal welfare (**Figure 1**). For example, cattle can be selected that have genetic traits that allow them to have improved disease resistance, and be more adaptable to their

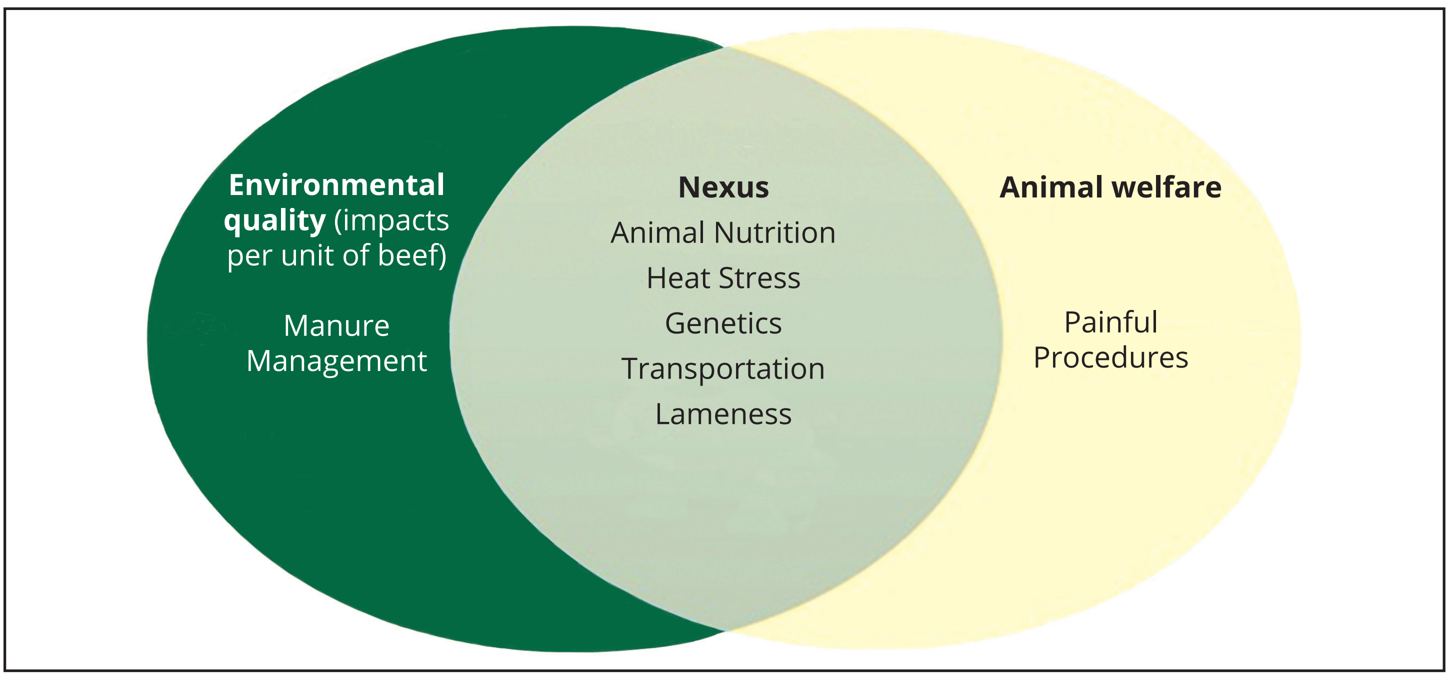


Figure 1. The nexus between environmental impact per unit of beef produced and cattle welfare. Items listed in the nexus are issues that can be "win-wins" (e.g., if the heat stress cattle experience can be mitigated, their productivity improves, thereby decreasing environmental impacts per unit of beef).*

*Adapted from Place and Mitloehner, 2014[3] environment. In turn, those traits could improve the lifetime efficiency of cattle to convert feed into body weight gain, as cattle that are ill tend to have lower feed conversion efficiencies. Improving lifetime feed efficiency lowers environmental impact and natural resources required per unit of beef, and lowers the cost of production for beef producers. As the preceding example demonstrates, the health and welfare of cattle is inextricably linked to beef sustainability, beyond just social acceptance and responsibility to the animals under a farmer or rancher's care.

Another example of the impact of cattle health and welfare on beef sustainability is transportation. The cow-calf phase of beef production is widely distributed across the United States and encompasses more than 765,000 farms that have an average cow herd size of 79 cows and wean an average of 73 calves per year.[4] However, cattle finishing typically takes place in feedlots that are concentrated in certain geographic locations (e.g., the High Plains); therefore, some cattle must be transported long distances during their lifetimes. Transportation can be a stressful situation for cattle due to handling, noise, stocking density, journey duration, and various other factors.[3,5] The stress of transportation can result in decreased immune function, decreased feed intake, and increased illness and mortality.[3] One management technique to help cattle cope with these stressors is called preconditioning, meaning they undergo a vaccination, nutrition, and management program for 30-60 days after weaning.[5] Aside from preconditioning, creating a low-stress environment prior to, during, and upon arrival is essential to managing cattle stress. To accomplish this, cattle are handled and managed properly by trained personnel.[3] The stress level of the animal upon arrival at a harvesting facility drastically affects the quality of the meat obtained from the animal. Meat from highly stressed cattle tends to be dark and tough, whereas cattle that are less stressed produce a much more desirable and tender product.[6] Reducing stress associated with transportation results in healthier animals, higher quality beef products, and decreased food waste, all of which reduces the environmental impact per unit of beef.[3]

Some stressors that cattle experience, such as weather extremes, are unavoidable. Thermal stressors affect cattle health, productivity, growth, and reproductive performance even long after the weather event occurs.[3,5] Mitigating the effects of weather extremes is not always feasible, particularly because cattle spend the majority of their lives outdoors. However, some management interventions can improve both animal comfort and productivity, which has a positive impact on the environment. Providing shade or sprinklers in the summertime and shelters or wind breaks in the wintertime can reduce thermal stresses. Reducing thermal stressors improves feed-to-gain ratios, reproductive success, and final carcass weight, thereby simultaneously improving animal welfare and lowering environmental impacts per unit of beef.[3,5]

While eliminating all stressful events from beef production is unrealistic in the same way that we do not live our lives completely without stress, management techniques and genetic selection can be used to reduce cattle stress, resulting in simultaneous improvements of animal health and welfare. Animal health and welfare go hand-in-hand with reducing environmental impact and maintaining economic viability.

Bottom Line: **Animal health and welfare are vital to beef sustainability. Healthy and comfortable animals have higher production efficiencies and less impact on the environment. Beef producers positively impact all three components of sustainability (environmental, social, and economic) through their commitment to animal health and welfare.**

Literature Cited

[1]Battagliese, T., J. Andrade, I. Schulze, B. Uhlman, C. Barcan. 2013. More sustainable beef optimization project: Phase 1 final report. BASF Corporation. Florham Park, NJ.

[2]Shields, S. and G. Orme-Evans. 2015. The impacts of climate change mitigation strategies on animal welfare. Animals. 5(2):361-394.

[3]Place, S.E. and F.M. Mitloehner. 2014. The nexus of environmental quality and livestock welfare. Annu. Rev. Anim. Biosci. 2:1.1-1.15.

[4]McBride, W.D. and K. Mathews Jr. 2011. The diverse structure and organization of U.S. beef cow-calf farms. EIB-73. U.S. Dept. of Agriculture, Econ. Res. Serv. March 2011.

[5]Lyles, J.L. and M.S. Calvo-Lorenzo. 2014. BILL E. KUNKLE INTERDISCIPLINARY BEEF SYMPOSIUM: Practical developments in managing animal welfare in beef cattle: What does the future hold? J. Anim. Sci. 92:5334-5344.

[6]Hocquette, J.F., R. Botreau, I. Legrand, R. Polkinghorne, D.W. Pethick, M. Lherm, B.Picard, M. Doreau, and E.M.C. Terlouw. 2014. Win-win for high beef quality, consumer satisfaction, and farm efficiency, low environmental impacts and improved animal welfare. Anim. Prod. Sci. 54:1537-1548.

For more information, contact:

National Cattlemen's Beef Association
Contractor to the Beef Checkoff Program
9110 East Nichols Avenue
Centennial, CO 80112
303.694.0305

BEEF FACTS: SUSTAINABILITY

BEEF RESEARCH

Fact Sheet 12 in the Series: Tough Questions about Beef Sustainability

Do feedlots have the largest greenhouse gas impact in the beef value chain?

Ashley Broocks, Megan Rolf and Sara Place
Oklahoma State University

The beef value chain is a complex system, which includes the production of feed, the raising of beef cattle on grass and in feedlots, processing plants, retailers, food service operations, and the consumer. Broadly, the beef value chain can be split into pre-farm gate (all the processes and activities prior to the harvest of the beef animal) and post-farm gate (all the processes and activities that take place once the beef animal leaves the farm, ranch, or feedlot). Approximately 80% of greenhouse gas (GHG) emissions produced per unit of beef in the United States occur in the pre-farm gate part of the beef value chain.[1] The pre-farm gate portion of the beef value chain can be split into three major phases: the cow-calf phase, the stocker or backgrounding phase, and the feedlot or finishing phase.

Feedlots are often believed to be responsible for the largest portion of beef's GHG emissions. In reality, the cow-calf phase is responsible for most (approximately 70%, **Figure 1**) of the GHG emissions in the beef value chain prior to the harvest of beef cattle.[2-5] Factors that influence GHG emissions in each phase deal with three primary components: the number of animals maintained in each phase at any given time, the diet of the animals in each phase, and efficiency of feed conversion.

Animals in the cow-calf phase are either pregnant or lactating cows, replacement heifers, growing

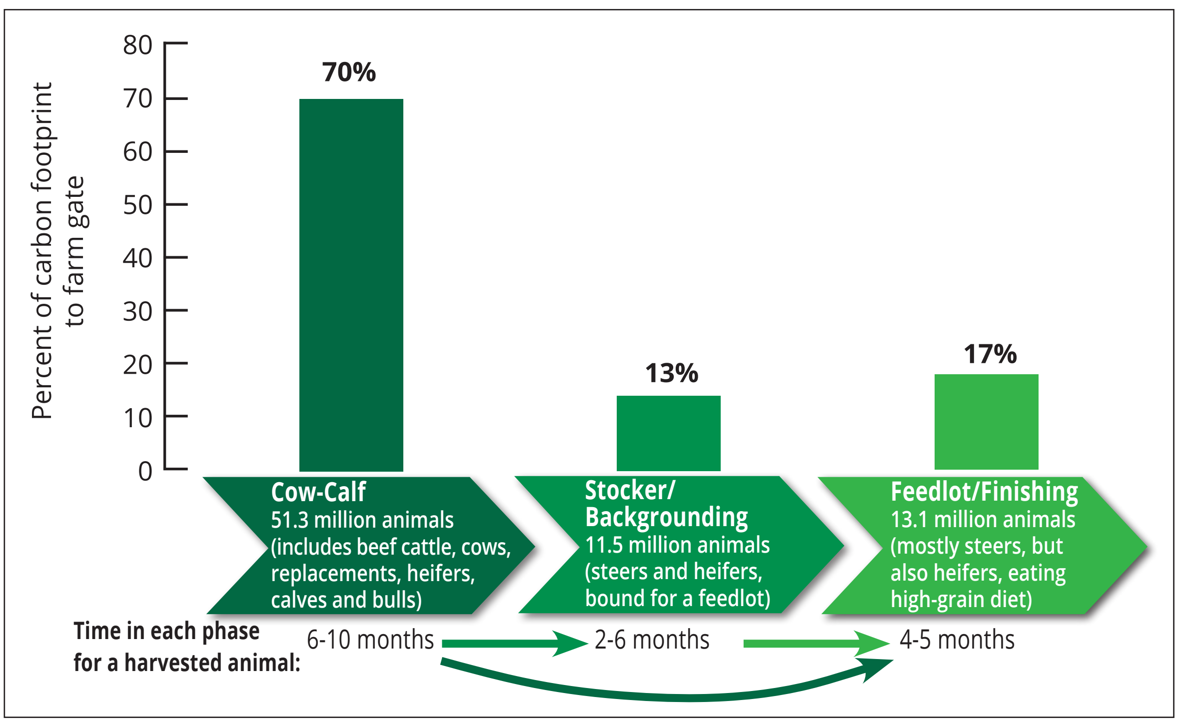


Figure 1. Average percentage[2-5] of the carbon footprint to the farm gate (i.e., greenhouse gas emissions generated per pound of beef prior to harvest of the cattle) due to the cow-calf, stocker/backgrounding, and feedlot/finishing phases of beef production and number of animals in each phase, as of January 1, 2015.[7]

calves, or bulls. Cows that are lactating have higher daily energy and nutrient requirements than other mature, non-lactating animals. Cattle in the cow-calf phase of the industry are largely raised on pasture, consuming mostly forages that are typically of lower quality or digestibility. It has been well established by scientific research that cattle consuming feed with low digestibility tend to generate more methane emissions (a GHG 28 times more potent at trapping heat in the earth's atmosphere than carbon dioxide[6]) as compared to cattle eating more digestible feed (e.g., cattle in feedlots eating high-grain diets).[5] While cattle in the cow-calf phase produce more methane emissions per animal due to their diet of mostly grass and hay, those feeds are also unsuitable for human consumption; therefore, there is a sustainability tradeoff between methane emissions and the ability of cattle to convert grass into human usable products (e.g., beef, leather).[2]

From the cow/calf sector, cattle are typically weaned and sold and enter the stocker/backgrounding phase, where they spend additional time grazing forage. However, the GHG emissions from the stocker/backgrounding phase are lower because the number of animals maintained in this phase is smaller, and they spend a shorter amount of time in this phase. To put this in perspective, cattle generally have one calf per year as a function of their gestation interval (which is similar to that of a person), so an entire herd of cows must be maintained for an entire year to produce one year's worth of cattle that may spend approximately 120 days in the backgrounding phase. Occasionally, weaned animals enter the feedlot directly and skip the stocker/backgrounding phase altogether.

Cattle in feedlots are given a nutritionally balanced diet to optimize growth and feed efficiency, or the conversion of feed into body weight gain. In this stage of production, animals can also receive growth promotants such as hormone implants or feed additives to further improve feed efficiency. Higher feed efficiency leads to lower methane emissions per animal due to improved digestibility, shorter time spent in the phase, and lower animal population in the feedlot/finishing phase as compared to the cow-calf phase which translates into lower GHG emissions (**Figure 1**).

While GHG emissions cannot be eliminated during the production of beef (or any other food product), there are opportunities to reduce GHG emissions throughout the entire beef value chain including both the cow-calf and feedlot/finishing phases. Growth promotants used in the stocker/backgrounding and feedlot/finishing phase have been shown to reduce GHG emissions per unit of beef by 9%.[8] Research using computer models has shown that 17% reductions in GHG emissions per unit of beef may be possible from the cow-calf phase by improving forage quality, land management, and increasing the number of calves weaned per cow every year (currently, not every cow weans a calf each year).[9]

Bottom Line: **Feedlots produce approximately 17% of the GHG emissions in the beef value chain that occur prior to the animal being harvested. The cow-calf phase of beef production produces a larger proportion of GHG emissions per unit of beef as compared to the feedlot phase. This is because there are more animals in the cow-calf phase and animals in the cow-calf phase consume a forage-based diet that increases the methane emissions released per animal.**

Literature Cited

[1]Battagliese, T., J. Andrade, I. Schulze, B. Uhlman, C. Barcan. 2013. More sustainable beef optimization project: Phase 1 final report. BASF Corporation. Florham Park, NJ.

[2]Beauchemin, K.A., H.H. Janzen, S.M. Little, T.A. McAllister, S.M. McGinn. 2010. Life cycle assessment of greenhouse gas emissions from beef production in western Canada: A case study. Agric. Syst. 103:371-379.

[3]Rotz, C.A., S. Asem-Hiablie, J. Dillion, and H. Bonifacio. 2015. Cradle-to-farm gate environmental footprints of beef cattle production in Kansas, Oklahoma, and Texas. J. Anim. Sci. 93:2509-2519.

[4]Rotz, C.A., B.J. Isenberg, K.R. Stackhouse-Lawson, and E.J. Pollak. 2013. A simulation-based approach for evaluating and comparing the environmental footprints of beef production systems. J. Anim. Sci. 91(11):5427-5437.

[5]Stackhouse-Lawson, K.R., C.A. Rotz, J.W. Oltjen, and F.M. Mitloehner. 2012. Carbon footprint and ammonia emissions of California beef production systems. J. Anim. Sci. 90:4641-4655.

[6]IPCC. 2013. Climate change 2013: The physical science basis. Contribution of working group I to the fifth assessment report of the IPCC. Cambridge University Press. Cambridge, UK.

[7]USDA NASS. 2015. January 1 Cattle Inventory. http://usda.mannlib.cornell.edu/usda/nass/Catt//2010s/2015/Catt-01-30-2015.pdf Accessed December 16, 2015.

[8]Stackhouse, K.R., C.A. Rotz, J.W. Oltjen, and F.M. Mitloehner. 2012. Growth-promoting technologies decrease the carbon footprint, ammonia emissions, and costs of California beef production systems. J. Anim. Sci. 90:4656-4665.

[9]Beauchemin, K.A., H.H. Janzen, S.M. Little, T.A. McAllister, S.M. McGinn. 2011. Mitigation of greenhouse gas emissions from beef production in western Canada—Evaluation using farm-based life cycle assessment. Anim. Feed Sci. and Tech. 166-167:663-677.

For more information, contact:

National Cattlemen's Beef Association
Contractor to the Beef Checkoff Program
9110 East Nichols Avenue
Centennial, CO 80112
303.694.0305

BEEF FACTS: SUSTAINABILITY

BEEF RESEARCH

Fact Sheet 13 in the Series: Tough Questions about Beef Sustainability

How does food waste impact sustainability?

Greg Thoma, Ph.D.
University of Arkansas

Global food security and sustainability are emerging challenges for policy makers, producers, manufacturing companies, retailers, and consumers. Globally, about 1.3 billion tons of food per year is lost.[1] When compared to national greenhouse gas (GHG) emissions, the carbon footprint of lost food would be third behind the total emissions of China and the United States.[2] Food is lost or wasted throughout the entire life cycle, from agricultural production to final household consumption, resulting in avoidable economic and environmental impacts. Therefore, a fuller characterization of food loss in each supply chain stage, as a function of consumption patterns associated with different rates of loss for different commodities, coupled with an assessment of the potential environmental impacts of food loss will help to identify opportunities to improve resource efficiency.

A tiered, hybrid, input-output (IO)-based life cycle assessment (LCA)[3] was conducted to quantify the potential environmental impacts of food loss associated with current food comsumption patterns and USDA Center for Nutrition Policy and Promotion (CNPP) Food Pattern (FP) recommendations[4] (**Figure 1**). Each food group was modeled using a sectoral analysis based on the U.S. Department of Commerce, Bureau of Economic Analysis (BEA) commodity groups with environmentally extended IO (EEIO)[5] coupled with process models for the post-production distribution and management of the food waste.

Important Findings

The total avoidable and unavoidable U.S. food losses over the whole life cycle of each food group at the primary, retail, and consumer levels aggregates to 105 million tons (232 billion pounds) per year under current consumption patterns, and represents 45.2% (overall breakdown shown in **Figure 1**) of annual U.S. food production by weight. It increases to 148 million tons (326 billion pounds) of projected food loss per

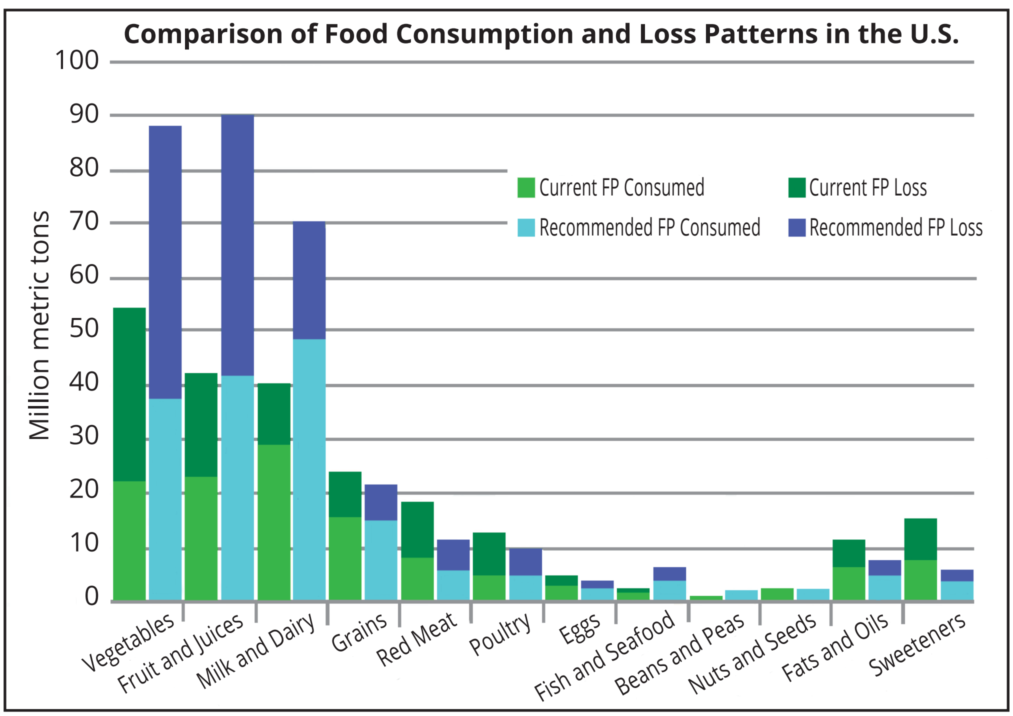


Figure 1. Food consumption and loss under current consumption pattern and CNPP-recommended pattern.

year if all U.S. citizens adopted the USDA dietary guidelines, assuming the same fractional loss rates for each food category in both scenarios. The full life cycle estimation of the lost food results in total GHG emissions of 410 million tons of carbon dioxide equivalents (CO_2e) per year (3.68 kg CO_2e capita^{1} day^{-1}) for current consumption, and it increases to 506 million tons CO_2e per year (4.53 kg CO_2e capita^{-1} day^{1}) for USDA recommendations (**Figure 2**). Under current consumption patterns, food loss by the total red meat group including unavoidable loss is the single largest GHG emissions contributor, representing 38.6% (158 million tons CO_2e emissions per year) of the total. Based on the USDA-recommended FP, food losses by the fruit/juices (26.7%) and milk/dairy (21.3%) groups become the two major GHG emissions contributors followed by vegetables (18.6%). Similar changes were observed for several other impact categories. Smog formation and acidification show no difference between the two scenarios and eutrophication is the only category for which impacts of food loss for the recommended diet has a lower impact, as shown by the contribution analysis in **Figure 3**. Shifting dietary patterns towards the USDA dietary guidelines results in an increase of 23.2% in GHG emissions and increases in other environmental impact categories. The recommended reductions in red meat, poultry, grains, eggs, fats/oils and sweeteners consumption and associated losses decrease GHG emissions, but this is offset by increases in vegetables, fruit/juices, and milk/dairy consumption and emissions associated with those losses.

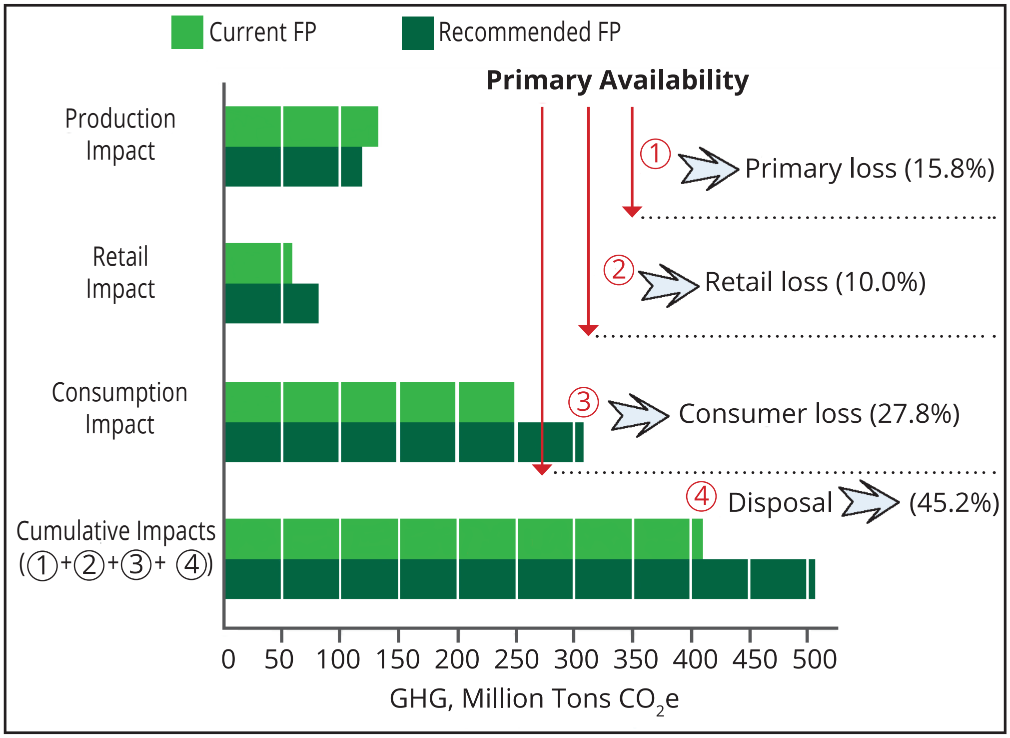


Figure 2. Supply chain model and distribution of greenhouse gas emmissions due to food waste.

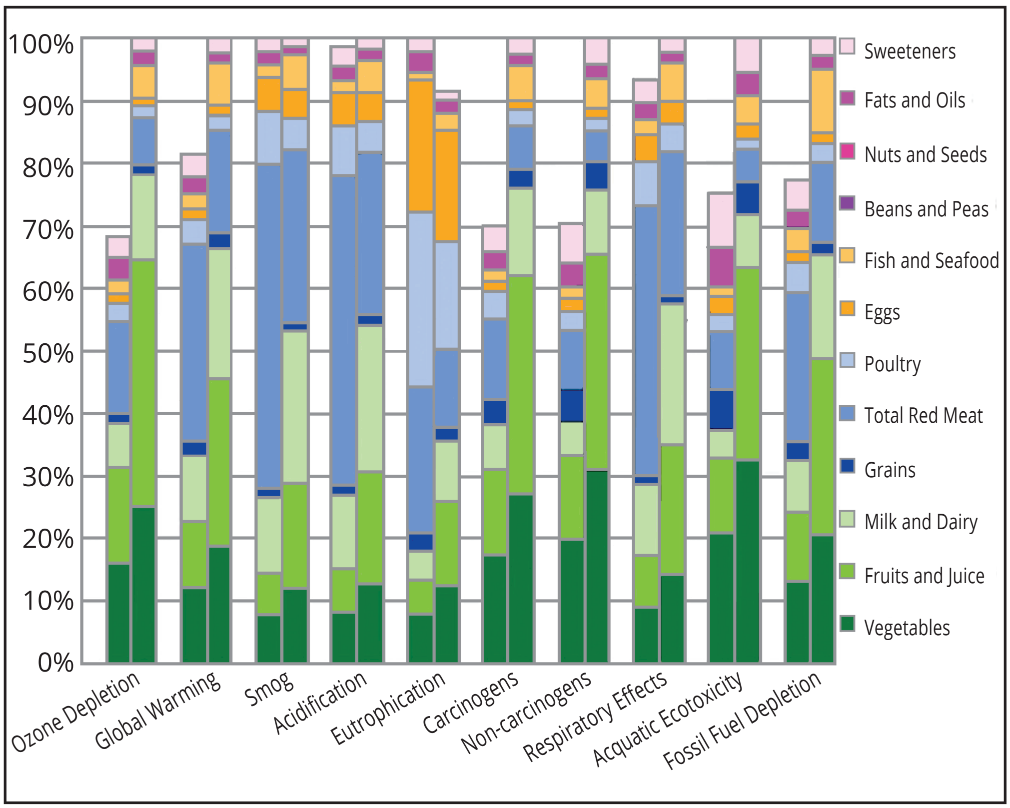


Figure 3. Relative contribution of food waste from each food group to environmental impact based on the current FP consumption (left column) and recommended FP consumption (right column). The legend at right is read from bottom to top matching the pattern.

***Bottom Line:* Due to the tremendous impacts associated with food waste, and as sustainability becomes a topic considered in dietary recommendations,[6] the incorporation of a full life cycle perspective of the diet into these considerations is essential.**

Literature Cited

[1]Gustavsson, J., Cederberg, C., Sonesson, U., van Otterdijk, R., Meybeck, A. 2011. Global food losses and food waste: extent, causes and prevention. Food and Agriculture Organization of the United Nations, Rome, Italy.

[2]Olivier Jan, C. Tostivint, A. Turbé, C. O'Connor, and P. Lavelle. 2013. Food wastage footprint. Impacts on natural resources. Summary Report. United Nations Food and Agriculture Organization, Rome, Italy.

[3]Kim, D., C. Scrafford, L. Barraj, E. Barnett, S. McNeill, K. Stackhouse-Lawson, and G. Thoma. Life cycle assessment of food loss associated with current US consumption compared to the recommended USDA Food patterns. Resour. Conserv. Recycl.

[4]USDA and USDHHS. 2010. Dietary Guidelines for Americans. 7th Ed., U.S. Department of Agriculture and U.S. Department of Health and Human Services, Washington, D.C.: U.S. Government Printing Office.

[5]Suh, S. 2005. Developing a sectoral environmental database for input–output analysis: the comprehensive environmental data archive of the US. Econ. Syst. Res. 17:449–469. Available from: http://www.tandfonline.com/doi/abs/10.1080/09535310500284326

[6]Ministry of Health of Brazil. 2014. Dietary Guidelines for the Brazilian for the Brazilian. Available from: http://www.foodpolitics.com/wp-content/uploads/Brazilian-Dietary Guidelines-2014.pdf

For more information, contact:

National Cattlemen's Beef Association
Contractor to the Beef Checkoff Program
9110 East Nichols Avenue
Centennial, CO 80112
303.694.0305

BEEF FACTS: SUSTAINABILITY

BEEF RESEARCH

Fact Sheet 14 in the Series: Tough Questions about Beef Sustainability

Are residues of the growth hormones used in cattle in our drinking water?

Ashley Broocks. Emily Andreini, Megan Rolf and Sara Place

Hormones are naturally produced by the endocrine system of humans and other animals, and regulate growth, development, and reproductive processes. Plants also produce hormones, or plant regulators, which are chemical substances that influence growth and specify cell function. Hormones and their metabolites are excreted out of the body of humans and other animals in the feces and urine, which may be used to supply nutrients as fertilizer, but often end up in the environment through manure disposal or manure runoff. Endogenous hormones are naturally produced in the body, whereas exogenous hormones are produced outside of the body. Exogenous hormones are derived from either natural or synthetic sources, and are incorporated into products such as birth control pills or hormone implants used in livestock. Cattle producers have been using hormone implants in cattle for more than 50 years in order to increase growth rates and feed efficiency.

Figure 1. A stream that has been fenced off to prevent cattle access. This management practice by farmers and ranchers can minimize the risk of hormones excreted by cattle from entering water supplies.

Currently, six hormones are approved for use in cattle: three natural (estradiol, testosterone, and progesterone) and three synthetic (melengestrol acetate [MGA], trenbolone acetate [TBA], and zeranol). The synthetic hormones are chemically similar to and mimic the actions of natural hormones. Some of these hormones are feed additives utilized over a short time span to regulate the estrus cycle and synchronize breeding in females such as with MGA. Others are small inserts placed under the skin of the ear to enhance growth of lean tissue and increase feed efficiency. The implants cattle receive contain low doses of hormones, which translates into little difference in the concentrations of hormones in the beef consumers eat.

Cattle are typically implanted upon arrival at the feedlot and the hormones can be detected in the manure the day after implantation.[1,2] While both exogenous and endogenous hormones can quickly make their way through the body and be detected in the manure, the hormones also degrade relatively quickly when they enter the environment.[3] For example, TBA and estradiol are the two most common hormones used in beef production.[3] Their presence in manure can quickly be detected after implantation, but degradation of TBA and estradiol occurs within 5.1 days and 12.4 days, respectively, in feces and 9.5 days and 8.6 days, respectively, in urine.[3] The rate of degradation for these hormones increases when urine and feces are mixed with soil, as happens on the surface of feedlot pens.[3] Soil contains natural microorganisms that can break down the carbon-rich backbone of steroids to use as an energy source.[4]

The quick breakdown of hormones in the environment is advantageous and limits their environmental impact, but producers are implementing additional manure management practices to minimize the impact potential. Mechanical separation is a promising technique to remove the hormones that are not degraded naturally from the environment.[5] The process is completed by placing the manure into a tank and using mechanical or chemical means to separate urine from feces.[5] The hormones remain with the solid material, allowing the liquid portion to still be used as agricultural fertilizer without risk of adding excess hormones to the environment or water supply.[5] Composting and utilizing microorganisms have been successful in dramatically reducing the concentration of hormones in manure by allowing time for the natural process of degradation to further break down hormones. The microorganisms can be used to speed up the breakdown process by either hydrolyzing or oxidizing hormones which renders them inactive.[4,6] Other beneficial management practices include maintaining grass buffers between sites of manure application and waterways (**Figure 1**) and increasing aeration in manure-holding lagoons.

While some research has found steroid hormones in very small concentrations downstream from feedlots, none have been found in tap water supplies meant for human drinking water.[7] Water treatment in the United States is highly effective in removing steroid hormones from drinking water, and though our detection methods are extremely sensitive, steroid hormones have not been detected in drinking water in concentrations at which a physiological effect could be expected. Regardless, reducing the amount of hormones from beef production in surface waters is vital to the health and welfare of aquatic and avian species[1-5] and the quality of the water supply. However, it is important to consider our own contribution to hormone contamination in water sources.[6] Human wastewater facilities and septic systems are common contributors of hormones into freshwater sources. In fact, solids from wastewater treatment plants are land-applied. Therefore, implementing better management practices for humans discarding hormone supplements or other pharmaceuticals is essential in maintaining water quality.[6]

Bottom Line: **Cattle production does contribute to the amount of natural and synthetic hormones found in the environment. However, the short lifespan of these hormones as well as natural degradation and manure management practices reduce the impact of these compounds on the environment. There is no evidence that growth hormones used in cattle are in tap water supplies meant for human drinking water use.**

Literature Cited

[1]Blackwell, B.R., T.R. Brown, P.R. Broadway, M.D. Buser, J.C. Brooks, B.J. Johnson, G.P. Cobb, and P.N. Smith. 2014. Characterization of trenbolone acetate and estradiol metabolite excretion profiles in implanted steers. Environ. Toxi. and Chem. 33:2850-2858.

[2]Webster, J.P., S.C. Kover, R.J. Bryson, T. Harter, D.S. Mansell, D.L. Sedlak, and E.P. Kolodziej. 2012. Occurrence of trenbolone acetate metabolites in simulated confined animal feeding operation (CAFO) runoff. Environ. Sci. Technol. Lett. 46:3803-3810.

[3]Blackwell, B.R., B.J. Johnson, M.D. Buser, G.P. Cobb, and P.N. Smith. 2015. Transformation kinetics of trenbolone acetate metabolites and estrogens in urine and feces of implanted steers. Chemosphere. 138:901-907.

[4]Young, R.B. and T. Borch. 2009. Sources, presence, analysis, and fate of steroid sex hormones in freshwater ecosystems – A review. In: Aquatic Ecosystem Research Trends. ed. G.H. Nairne, 103-164. New York: Nova Science Publishers.

[5]Hansen, M., E. Bjoklund, O. Popovic, L.S. Jensen, C.S. Jacobsen, D.L. Sedlak, and B. Halling-Sorensen. 2015. Animal manure separation technologies diminish the environmental burden of steroid hormones. Environ. Sci. Technol. Lett. 2:133-137.

[6]Biswas, S., C.A. Shapiro, W.L. Kranz, T.L. Mader, D.P. Shelton, D.D. Snow, S.L. Bartlet-Hunt, D.D. Tarkalson, S.J. van Donk, T.C. Zhange, and S. Ensley. 2013. Current knowledge on the environmental fate, potential impact, and management of growth-promoting steroids used in the U.S. beef cattle industry. J. Soil and Water Conserv. 68(4):325-336.

[7]Soto, A.M., J.M. Calabro, N.V. Prechtl, AY. Yau, E.F. Orlando, A. Daxenberger, A.S Kolok, L.J. Guillette, Jr., B. Le Bizec, I.G. Lanfe, and C. Sonnenschein. 2004. Androgenic and estrogenic activity in water bodies receiving cattle feedlot effluent in Eastern Nebraska, USA. Environ. Health Persp. 112:346-352.

For more information, contact:

National Cattlemen's Beef Association
Contractor to the Beef Checkoff Program
9110 East Nichols Avenue
Centennial, CO 80112
303.694.0305

BEEF FACTS:
SUSTAINABILITY

BEEF
RESEARCH

Fact Sheet 15 in the Series: Tough Questions about Beef Sustainability

Why is sustainability so difficult to define?

Megan Rolf, Kansas State University

Sustainability is a term that is frequently used in a variety of industries, including beef production. The term has appealing attributes and there are likely few people who would not advocate for more sustainable production practices in many industries. But what is sustainability? If you ask 10 people, you are apt to receive 10 different answers. The definition of sustainability generally encompasses three different aspects of production: Environment, Social, and Economic. When all stakeholders in the beef value chain, from producers to retailers and consumers, agree that we want to raise beef in the most sustainable manner possible, why is it difficult to agree on what that production system looks like? The answer to that question is underpinned in the definition of "wicked" problems.

Sustainability is a "wicked problem."

Wicked problems are termed such because they often have ambiguous solutions and intended goals which may be unattainable. To simplify, wicked problems are "complex, ill-defined, messy and unsolvable."[2] Let's put this definition to the test using four criteria (**Box 1**) to exemplify how sustainability is "wicked."

First, no definitive definition exists. Due to the difficulties inherent in defining sustainability, many working definitions contain three different attributes: economic viability, environmental stewardship, and social responsibility. However, a challenge arises if we move toward adding more specifics to the definition, as the opportunities to debate the priority of each of these facets of sustainability, the weighting that should be placed on each, and how to establish specific metrics and measure the outcomes could be boundless. With this level of complexity and ambiguity, a specific "one-size-fits-all" definition of sustainability becomes untenable.

The definition of a wicked problem was summarized by H.C. Peterson[1] to include four criteria:

1. No definitive definition of the problem exists
2. The solution to the problem is not binary- it can only be described as better or worse rather than solved or not solved
3. Varying priorities of stakeholders result in dramatically different perspectives on the problem
4. The relationships that underlie the problem are complex, systemic, and either unknown or very uncertain

Box 1. Criteria of a wicked problem.

Secondly, the solution is not binary. Because there is no standard, measurable definition of sustainability that perfectly sums up all possible sustainability priorities, sustainability can never be reached in the classic sense. A system can become more or less sustainable as it moves closer or further from the priorities, but it is not a "sustainable or not" classification. Just as in the adage, "It's the journey, not the destination," systems can alter their practices to be more in line with the ideals of sustainability, but there is no definitive threshold where one could say a system is sustainable.

Third, varying frames of reference skew stakeholder perception of the issue. Sustainability will be defined or weighted more heavily towards those aspects that are most important to that group or person's goals and priorities. As with any complex issue, failing to take into account the perspectives of other stakeholders leaves no "common ground." In order to show progress towards attaining a goal such as sustainability, groups must define, discuss, redefine, and compromise with other stakeholders to establish reasonable, achievable priorities that work for everyone. Of course, the larger and more diverse the group of stakeholders, the more perspectives and priorities that must be balanced. Sustainability in the beef industry is an excellent example because of the large variety of stakeholders and priorities, including cow/calf producers, stocker operators, feedlots, packers, retailers, foodservice operators, consumers, landowners, and non-governmental organizations.

Lastly, the system is complex and interdependent, often with unknown outcomes. By definition, almost all biological systems will fit into this category. Beef production occurs in nearly every geographic region within the United States, each with different environmental conditions. The impacts of a production system or conservation practice in one area may be completely different in another. In addition, there are stark differences between regions in regard to the abundance of natural resources and the practices necessary for conservation of these resources. As with any ecosystem or biological process, changes in a process or practice may have a "ripple effect" into the larger system as a whole. Because of this, production decisions must be made with careful consideration to consequences, intended and unintended, in the larger system. As a result, "better and worse" cannot always be easily defined, or measured, because of its ambiguity. To illustrate these points with some practical examples, let's compare and contrast differences in the three pillars of sustainability (environment, economic, social) of two different beef production systems: grain-finished and grass-finished. (**Figure 1**). Cattle finished in either system will spend the first part of their lives (the first 8-16 months) consuming primarily forage, or whole plants such as grass and hay; however, the finishing or last part of their lives will vary in the following ways:

1. In a **grain-finished** beef system cattle are finished in a feedlot for 4 to 6 months eating a diet that is typically 70% or greater grain-based.
2. In a **grass-finished** beef system cattle are finished on grass for a period of 6 to 10 months, with little to no grain supplementation to their diets.

Which is more sustainable? Suppose that the grass-finished system above encompassed two different systems: a system comprised of planted bermudagrass forage only, or a system comprised of native rangeland only. Each of these forage types will likely have differences in stocking density, diversity of grasses and forbs, and fertilizer use.[8, 9, 10, 11] Keeping in mind the fact that these metrics may be different for different forages or in different parts of the country, which is more sustainable? If the grazing is incorporated in a rotational cropping system to take advantage of crop residue or to graze cover crops, would that be more sustainable? What if any of these producers were forced to sell their cattle due to lack of profit or reduction of necessary natural resources

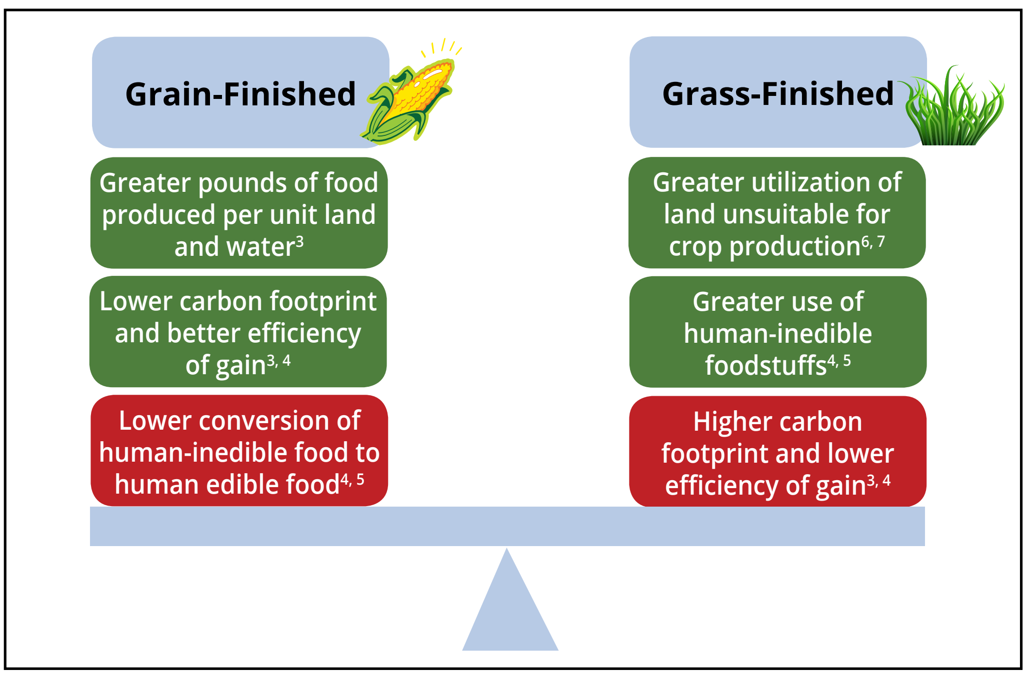


Figure 1. Contrasting some sustainability metrics for grain-finished vs grass-finished beef.

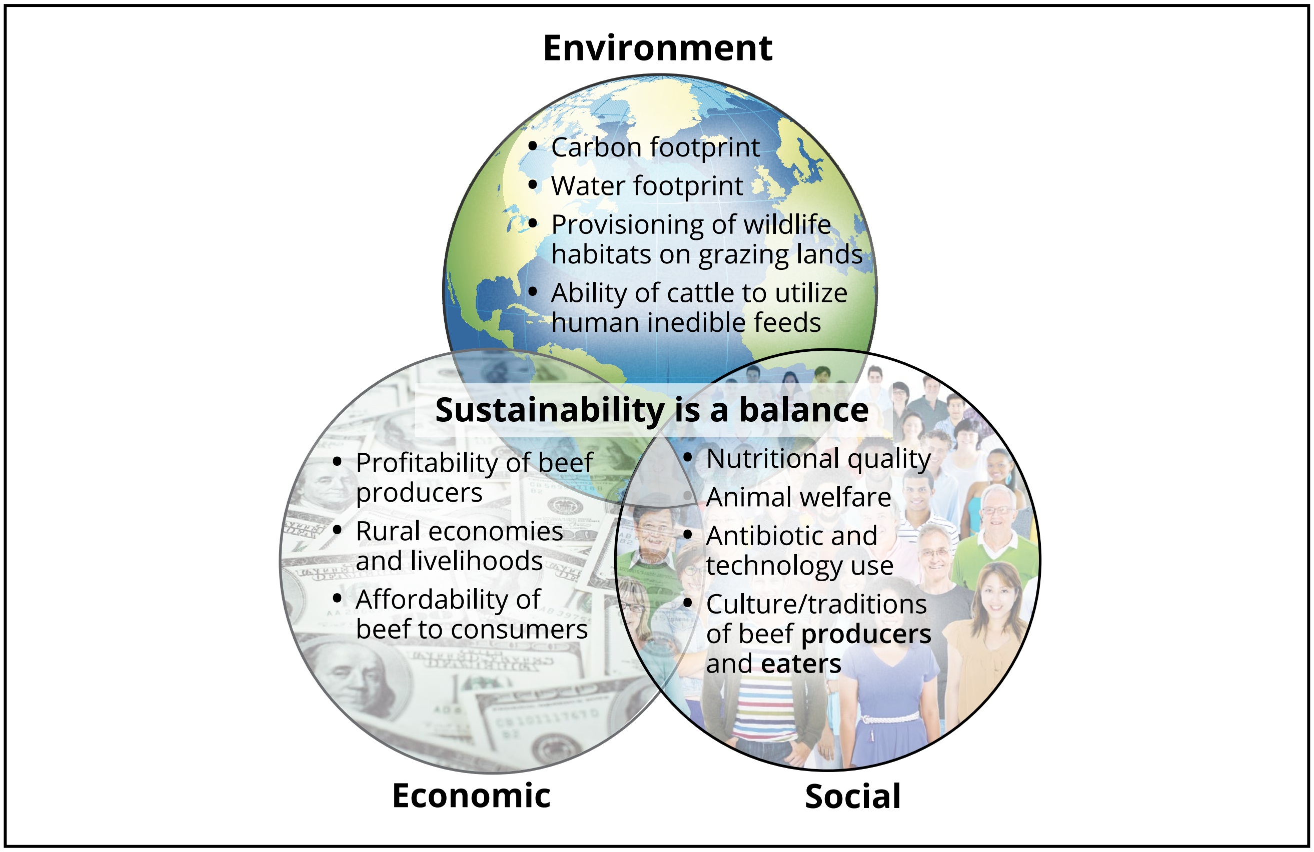


Figure 2. Examples of some of the issues that fall under the economic, environmental, and social aspects of beef sustainability.

— was it sustainable? If consumers were opposed to one of these production systems due to their perception of animal welfare, would that system still be sustainable? Each individual person will have their own priorities and perceptions that may color their initial answer. However, if we consider the complexity of these systems and the trade-offs in various metrics related to sustainability, no one system is an obviously more sustainable choice — all of these systems can be sustainable. No one system is definitively "correct", because each has its own positive and negative attributes and each can become more sustainable by focusing on continual progress towards improvements for each of the three pillars of sustainability.

Bottom line: Beef cattle production systems encompass a wide variety of management systems and environments. While one system may be very successful under one form of management and in one region of the country, that same management system may be unsuccessful in another. When considering various production systems with the three pillars of sustainability, it becomes clear why defining beef sustainability is such a wicked problem. However, even in the absence of a single universal definition and attainable sustainability goal, each beef production system can move forward and continuously improve its economic, environmental, and social sustainability.

References:

[1]Peterson, H.C. 2013. Sustainability: A wicked problem. In. Sustainable Animal Agriculture. Edited by E. Kebreab.

[2]Peterson, H.C. 2009. Transformational supply chains and the 'wicked problem' of sustainability: Aligning knowledge, innovation, entrepreneurship, and leadership. Journal on chain and network science, 9(2):71-82.

[3]Capper, J.L. 2012. Is the grass always greener? Comparing the environmental impact of conventional, natural and grass-fed beef production systems. Animals. 2:127-143

[4]Pelletier, N., R. Pirog, and R. Rasmussen. 2010. Comparative life cycle environmental impacts of three beef production strategies in the Upper Midwestern United States. Agric. Sys. 103:380-389.

[5]Wilkinson, J.M. 2011. Re-defining efficiency of feed use by livestock. Animal. 5:1014-1022.

[6]Capper, J.L. 2011. The environmental impact of beef production in the United State: 1977 compared with 2007. J. Anim. Sci. 89:4249-4261.

[7]Lubowski, R. N., M. Vesterby, S. Bucholtz, A. Baez, and M. J. Roberts. 2006. Major Uses of Land in The United States, 2002. Electronic report from the Economic Research Service. http://ageconsearch.umn.edu/bitstream/7203/2/ei060014.pdf

[8]Tilman, D. 1997. Community invisibility, recruitment limitation, and grassland biodiversity. Ecology. 78(1):81-92.

[9]Redfearn, D. 2006. Chapter 14: Fertilizing warm-season forages. In: Oklahoma Forage and Pasture Fertility Guide. http://npk.okstate.edu/documentation/factsheets/Pasutre%20Handbook/E-1021web.pdf

[10]United States Department of Agriculture National Resources Conservation Service. Chapter 5: Management of Grazing Lands. In: National Range and Pasture Handbook. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1043064.pdf

[11]Scasta, J.D., D.L. Lalman, and L. Henderson. 2016. Drought mitigation for grazing operations: Matching the animal to the environment. Rangelands. 38(4)204-210. http://www.sciencedirect.com/science/article/pii/S0190052816300281

For more information, contact:

National Cattlemen's Beef Association
Contractor to the Beef Checkoff Program
9110 East Nichols Avenue
Centennial, CO 80112
303.694.0305

BEEF FACTS: SUSTAINABILITY

BEEF RESEARCH

Fact Sheet 16 in the Series: Tough Questions about Beef Sustainability

Ecosystem Services — What are they and how do they relate to beef production?

Laura Goodman and Ryan Reuter
Oklahoma State University, Natural Resources Ecology and Management and Animal Science Departments

Because beef cattle producers often manage large tracts of land, they are managing ecosystems and ecosystem services. Those terms may be unfamiliar, but they describe simple and innately understood concepts.

What are Ecosystems?

Ecosystems are communities of living organisms interacting with their physical environment and one another. The living organisms include plants, animals, people, fungi, and bacteria, while the physical environment includes non-living components like sunlight, soils, water, air, and mineral nutrients. Each ecosystem community is unique in how its living and non-living components interact, but all healthy ecosystems provide critical goods and services necessary for human well-being.

What are Ecosystem Services?

Ecosystem services are the benefits which people obtain from the ecosystem (**Table 1**). In most cases, ecosystems provide these services at little or no financial cost. These benefits can accrue to an individual or to society as a whole.

The Beef Cattle Industry's Contribution to Ecosystem Services

Livestock production is generally categorized as a provisioning service. These services produce a commodity or product, in this case, beef. Products from beef cattle do not mean just steak and hamburgers though, because by-products from beef cattle are a part of our everyday lives. They are found in many goods like tires, sheetrock, antifreeze, insulin, clothing, and even deodorant.[3]

Grazing animals are important for providing food to people for two reasons: (1) they convert indigestible plant parts (fiber) into a form our bodies can absorb (protein) and (2) they provide a product from lands that are otherwise limited in their potential for human food production. Humans cannot breakdown cellulose, which is the primary component of fiber. Ruminants (cows, sheep, goats) consume high-fiber plants like grasses and convert it to valuable protein for human use. They can do this because of their specialized digestive systems.

Table 1. Examples of the goods and services from ecosystems by category[1, 2]

Ecosystem service category	Examples of ecosystem services within category
Provisioning	Food; Fresh water; Fiber; Fuelwood;
Supporting	Cycling of nutrients; Soil building, preservation, and fertility renewal; Photosynthesis
Regulating	Regulation of disease carrying organisms; Climate stability; Moderation of weather extremes; Agricultural pest control; Air and water purification; Polination of natural vegetation and crops; Decomposition and detoxification of wastes
Cultural	Support of spiritual and cultural heritage; Educational, aesthetic and recreational opportunities

Funded by the Beef Checkoff.

Many of the lands used for grazing beef cattle are rangelands or pastureland. These lands are characterized by limited use for cultivation due to shallow, fragile, or rocky soils, steep terrain, and/or low rainfall. Rangelands are the predominant land type across the world, making up 70% of the earth's land area. Meat from livestock grazing rangelands is an important product these ecosystems provide.[4]

The process of grazing also provides services like developing wildlife habitat by increasing plant species diversity and creating variation in plant structure as cattle select certain plants to eat over others[5] which is important for supporting a wide variety of wildlife species.

Lastly, beef cattle production in the United States promotes rural communities and provides a cultural service as the backdrop of our historical heritage as witnessed by many of our American songs and, stories.

Examples of Ecosystem Services Important to the Beef Cattle Industry

With nearly 94 million head of cattle in production in the United States and each animal capable of producing 19,800 pounds or 740 cubic feet of solid manure per year, disposing of their manure can be challenging. Luckily, beetles in the Scarab family (Scarabaeidae), commonly known as dung beetles, assist in decomposition of this waste on pastures and rangelands by burying the manure and incorporating it into the soil. The removal of dung from the soil surface reduces losses due to forage fouling ($122 million), nitrogen cycling that would have been lost to the environment ($58 million), and decreases habitats for parasites ($70 million) and flies ($130 million) for a total of $380 million of averted losses to the beef cattle industry in the United States.[6]

Alfalfa hay and supplements containing alfalfa products are commonly used as winter protein supplements in beef cattle production. The seed used to grow that alfalfa requires pollination by bees. In fact, alfalfa is the most valuable U.S. crop requiring pollination by bees. The value attributed to the pollination services provided by leaf cutter bees in alfalfa hay production was over $7 billion in 2008.[7]

Can Ecosystem Services Be Lost?

Poor grazing land management can reduce an ecosystem's ability to provide ecosystem services. On grazing lands, examples of poor management may include:

- Reduction in plant biodiversity from broadcast herbicide application or the introduction of invasive plant species
- Runoff of fertilizers, herbicides or pesticides[8]
- Soil erosion from overgrazing[9]
- Encroachment of woody plant species into their non-native habitat[10]

Bottom line:

Beef cattle production, including the proper management of grazing lands associated with it, is an important source of diverse ecosystem services to humans. In turn, beef production also benefits from ecosystem services.

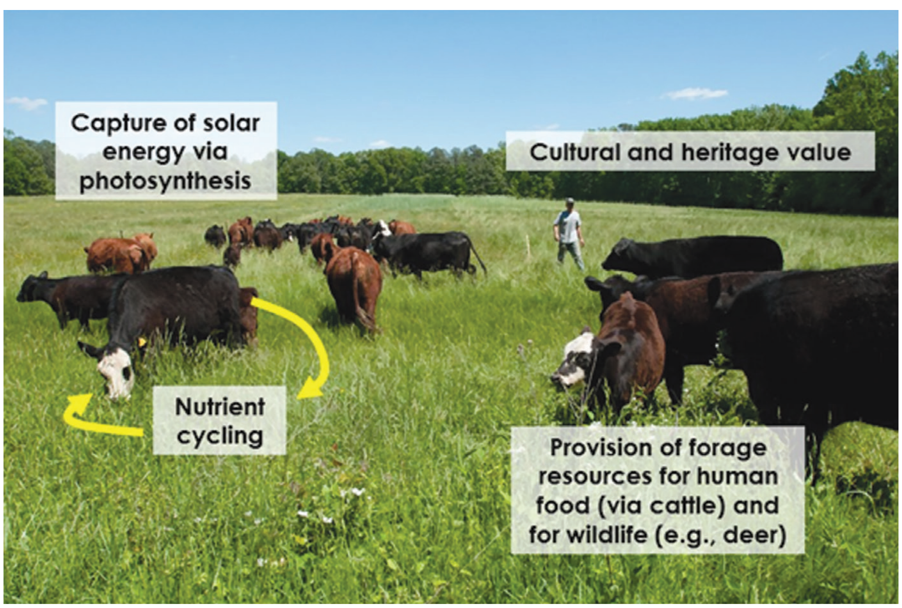


Figure 1. Examples of ecosystem services important to the beef industry and the beef industry's contribution to ecosystem services.

Photo courtesy of U.S. Department of Agriculture

References

[1]Daily, G. C., Susan Alexander, P. R. Ehrlich, L. Goulder, J. Lubchenco, P. A. Matson, H. A. Mooney, S. Postel, S. H. Schneider, D. Tilman, and G. M. Woodwell. 1997. Ecosystem services: Benefits supplied to human societies by natural ecosystems. Issues in Ecology 2:1-15.

[2]Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

[3]Jayathilakan, K., K. Sultana, K. Radhakrishna, and A.S. Bawa. 2012. Utilization of byproducts and waste materials from meat, poultry and fish processing industries: a review. Journal of Food Science and Technology 49:278-293.

[4]Holechek, J. L., R. D. Pieper, and C. H. Herbel. 2001. Range management: Principles and practices. Prentice Hall. Upper Saddle River, New Jersey, USA.

[5]Hartnett, D. C., K. R. Hickman, L. E. Fischer Walter. 1996. Effects of bison grazing, fire, and topography on floristic diversity in tallgrass prairie. Journal of Range Management 49:413-420.

[6]Losey, J. E., and M. Vaughan. 2006. The economic value of ecological services provided by insects. BioScience 56:311-323.

[7]Calderone, N. W. 2012. Insect pollinated crops, insect pollinators and US agriculture: Trend analysis of aggregate data for the period 1992–2009. PLoS ONE 7:1-27.

[8]Hart, M. R., B. F. Quin, and M. L. Nguyen. 2004. Phosphorus Runoff from Agricultural Land and Direct Fertilizer Effects: A Review. J. Environ. Qual. 33:1954–1972.

[9]Hogan, C. M. 2009. Overgrazing. Encyclopedia of Earth. Sidney Draggan, topic ed.; Cutler J. Cleveland, ed., National council for Science and the Environment, Washington DC.

[10]Wine, M. L., and J. M. H. Hendrickx. 2013. Biohydrologic effects of eastern red cedar encroachment into grassland, Oklahoma, USA. Biologia. 68: 1132. doi:10.2478/s11756-013-0252-9.

For more information, contact:

National Cattlemen's Beef Association
Contractor to the Beef Checkoff Program
9110 East Nichols Avenue
Centennial, CO 80112
303.694.0305

BEEF FACTS: SUSTAINABILITY

BEEF RESEARCH

Fact Sheet 17 in the Series: Tough Questions about Beef Sustainability

What are enteric methane emissions?

Ryan Reuter, Matt Beck, and Logan Thompson,

Oklahoma State University, Department of Animal Science

Beef cattle are ruminants, which means they have a specialized digestive tract with a four-compartment stomach. The largest of these compartments is the rumen. The rumen houses trillions of microbes (bacteria, protozoa, and fungi) that break down and digest the fiber and other carbohydrates that ruminants eat. The microbes and the animal have a mutually beneficial relationship – the microbes get a nice environment to live in and a constant supply of food, while the cattle receive the nutrients that the microbes liberate from the feed the cattle eat. Interestingly, without the microbes, the cattle would be just as unable to digest grass as humans.

As the microbes break down carbohydrates (cellulose, starch, etc.), they release glucose molecules, and these simple sugars are then fermented into several products. Some of these fermentation products, namely volatile fatty acids, are absorbed by the animal and used as an energy source to eventually power growth and milk production. One of the waste products of fermentation is methane, which is a greenhouse gas. Methane produced directly from the digestive tract of these animals is known as enteric methane.

According to the FAO, enteric methane emissions from domesticated ruminants (wild animals excluded) account for 30% of all global human-caused methane emissions. In the United States, beef cattle are responsible for just 18% of methane emissions, or 1.8% of total human-caused greenhouse gas emissions (**Figure 1**).[1]

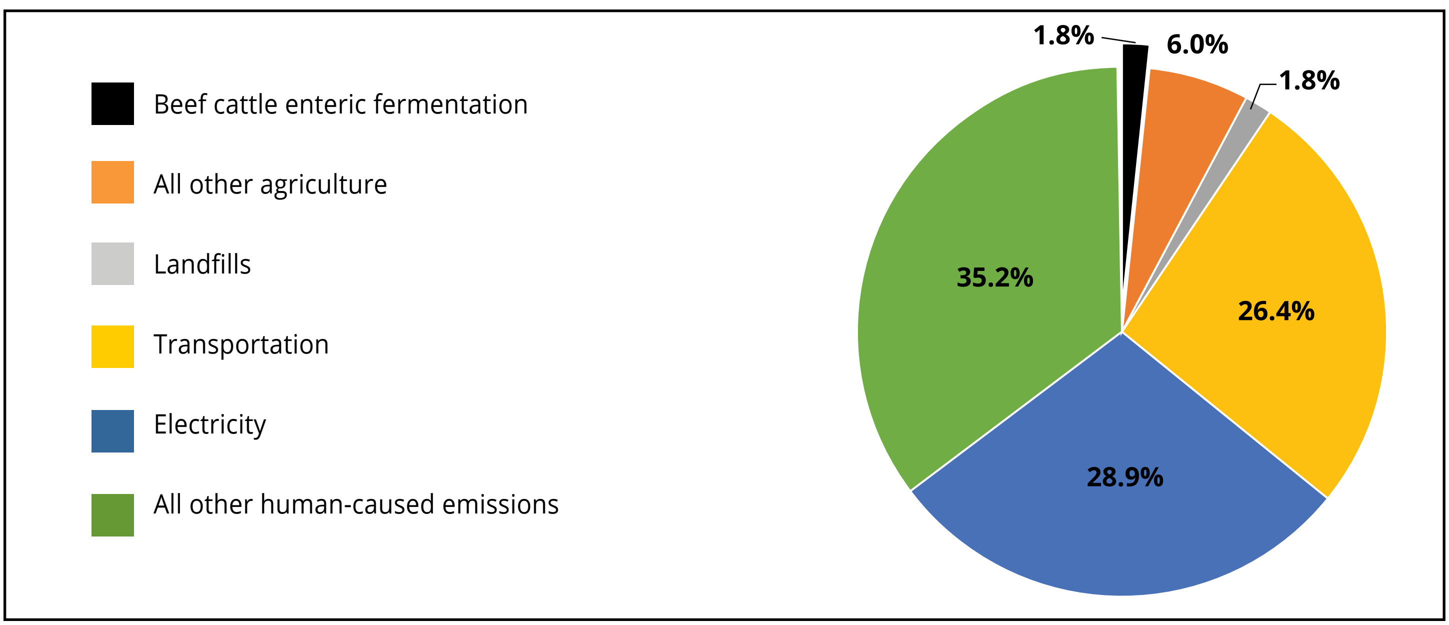


Figure 1. 2015 US Greenhouse Gas Emissions (GHG) Inventory in carbon dioxide equivalent emissions. Methane emissions from beef cattle represented 1.8% of all human-caused GHG emissions in the U.S. in 2015.[1]

Enteric methane emissions are expected to increase as the global population becomes larger and more affluent;[2] however, in the United States, enteric methane emissions from beef cattle have declined 34% since 1975.[3] The total amount of emissions from U.S. beef cattle are similar to the enteric methane emissions that were emitted by wild ruminants (e.g., bison, deer, elk) prior to the European settlement of North America (**Figure 2**).

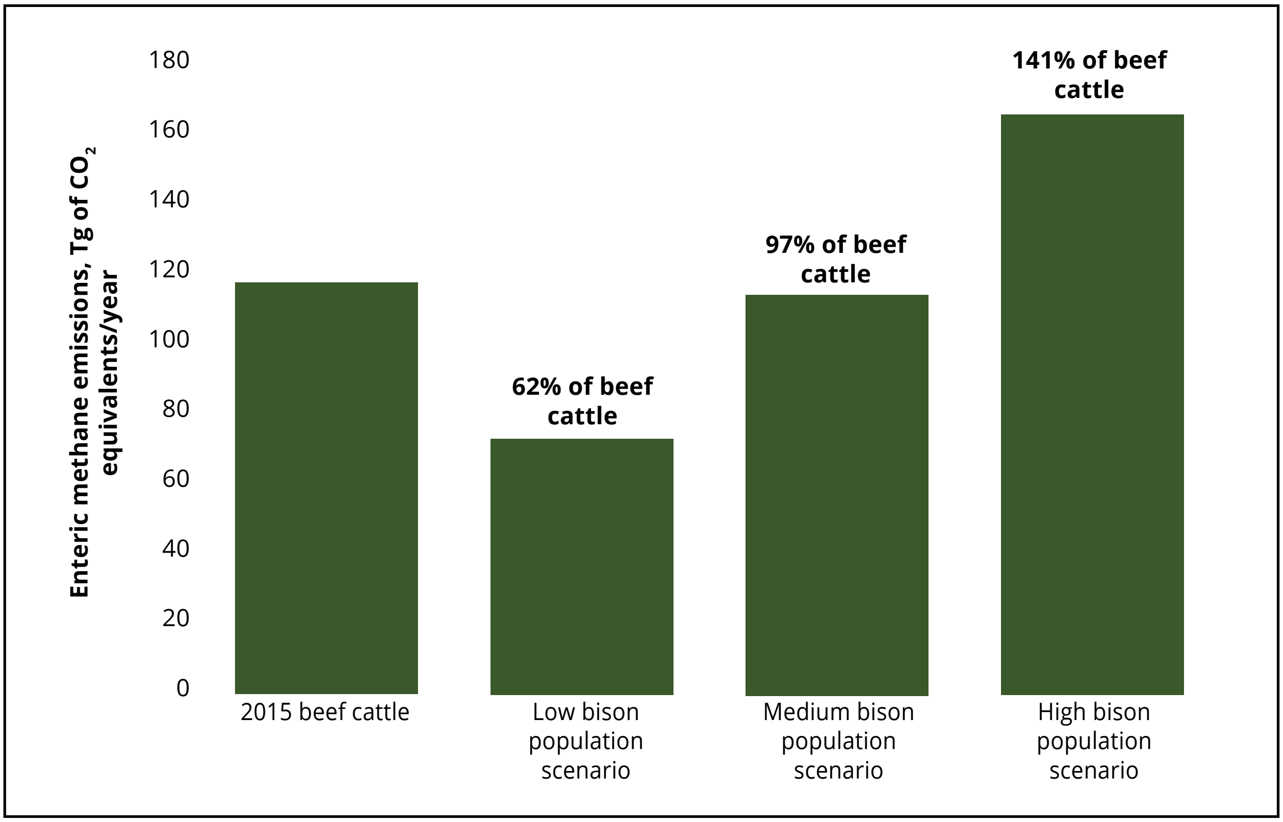


Figure 2. Comparison of enteric methane emissions from US beef cattle in 2015[1] to the estimated enteric methane emissions from wild ruminants prior to the 15th century.[11] The three scenarios represent three estimated bison population sizes (30, 50, or 75 million) as the exact size of bison herds is unknown.

It isn't possible to eliminate methane production from ruminants, short of eliminating the rumen. Obviously, this would be undesirable. Without ruminant animals, much of the land mass of Earth would be unusable for food production. Further, the ecology of many of our grazing lands depends on large herbivores, and cattle grazing is used to maintain these ecosystems in a productive, healthy state. Emissions of enteric methane is the cost of this unique service that ruminants provide. Rather than eliminating methane, reducing the amount of methane produced during food production is a sustainable goal.

Farmers and ranchers have an incentive to reduce enteric methane emissions not only for environmental reasons, but also because methane represents a loss of the energy value of feed. Thus, if methane emissions are lower as a percentage of feed energy intake, cattle can extract more calories from every pound of feed consumed to meet their energy needs.

There are several opportunities to alter the formation of enteric methane across all sectors of the beef industry.[6] The amount of methane an animal emits is mostly a function of how much feed it eats and the quality of that feed. Less feed consumed results in less methane produced, and higher-quality feeds (i.e., more digestible feeds) reduce the amount of methane produced per unit of feed consumed. Both factors can be managed in forage and feedlot systems through diet, feed supplements, etc.

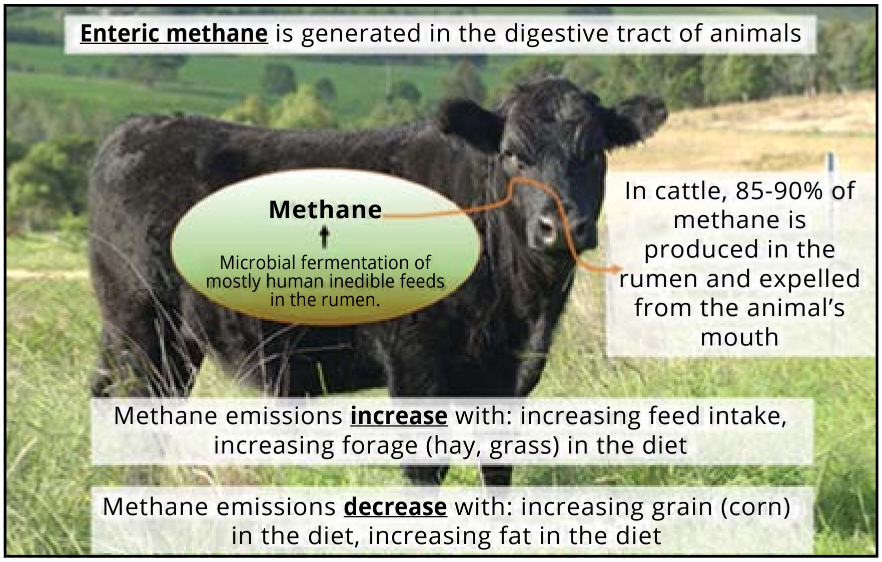


Figure 3. Key facts about enteric methane emissions from cattle. The production of methane is a naturel process and essential for normal rumen function.

Photo courtesy of Commonwealth Scientific and Industrial Research Organisation of Australia.

Enteric methane accounts for about 47% of the total carbon footprint of beef in the United States, when everything from cattle feed production to cooking energy in homes and restaurants is considered.[7] The nation's brood cow herd produces about 70% of beef cattle's carbon footprint in the United States.[8] Cows are typically grazed on forages, which have a greater propensity to produce methane than grains, like corn. A three-year study comparing a basic cow management system to one that utilized best management practices (fertilization, advanced grazing management, etc.) found that methane emissions from both systems varied across the year.[9] However, the best management practice system produced 22% less methane per cow than the basic system.[9]

Other approaches, such as supplementing a small amount of fat into the diet of ruminants, can reduce methane production. Certain supplements (ionophores, methane inhibitors, etc.) can be given to animals in very small amounts and alter the fermentation process to reduce methane, often improving feed efficiency of the animals.[6] While feedlot systems have a lower carbon footprint than forage-based systems, they still account for about 20% of the beef industry's carbon footprint.[8] Management practices such as grain processing can help. Steam flaking corn reduced methane per unit of feed consumed by 17%, compared to feeding dry rolled corn.[10]

Some of these management practices may not fit into all production environments. Cattle producers must balance methane emissions with other factors such as animal health, logistics, costs, ecology and genetics so that they can cost-effectively and sustainably produce food for the long run.

Bottom line: Enteric methane is a natural byproduct of the mutually beneficial relationship between ruminant animals and the specialized microbes in their gut. Methane must be released to protect the health of the animal and to maintain the viability of the microbes. Enteric methane emissions from beef cattle represent 1.8% of total US greenhouse gas emissions. Best management practices such as good grazing management and strategic feed supplementation help reduce enteric methane emissions from beef cattle and cost-effectively increase human food production, thereby improving sustainability.

References

[1]EPA. 2017. Inventory of U. S. Greenhouse Gas Emissions and Sinks: 1990-2015. U. S. Environmental Protection Agency, Washington, D. C.

[2]Gerber, P.J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., Falcucci, A., and Tempio, G. 2013. Tackling climate change through livestock – A global assessment of emissions and mitigation opportunities. Food and Agriculture Organization of the United Nations (FAO), Rome.

[3]U.N. Food and Agriculture Organization. FAOSTAT Database – Food and agricultural data. Accessed June 15, 2017, available at: http://www.fao.org/faostat/en/#home

[4]Hill J., C. McSweeney, A. G. Wright, G. Bishop-Hurley, K. Kalantar-zadeh. 2016. Measuring methane production from ruminants. Trends in Biotechnology. 34:26-35.

[5]McAllister T.A. Newbold. C. J. 2008. Redirecting rumen fermentation to reduce methanogenesis. Australian Journal of Experimental Agriculture. 48: 7-13.

[6]Hristov, A. N., J. Oh, J. L. Dijkstra, E. Kebreab, G. Waghorn, H. P. S. Makkar, A. T. Adesogan, W. Yang, C. Lee, P. J. Gerber, B. Henderson, and J. M. Tricarico. 2013. Mitigation of methane and nitrous oxide emissions from animal operations: I. a review of enteric methane mitigation options. J. Anim. Sci. 91:5045-5069.

[7]Battagliese, T., J. Andrade, R. Vinas, K. Stachouse-Lawson, C. A. Rotz, and J. Dillon. 2015. U.S. Beef – Phase 2 Eco-efficiency Analysis. http://www.beefresearch.org/CMDocs/BeefResearch/Sustainability%20Completed%20Project%20Summaries/BASF_NCBA%20US%20Beef%20Industry%20Phase2_%20NSF%20EEA%20Analysis%20Report_FINAL.pdf

[8]Rotz, C. A., B. J. Isenberg, K. R. Stackhouse-Lawson, and E. J. Pollak. 2013. A simulation-based approach for evaluating and comparing the environmental footprints of beef production systems. J. Anim. Sci. 91: 5427-5437.

[9]DeRamus, H. A., T. C. Clement, D. D. Giampola, and P. C. Dickison. 2003. Methane emissions of beef cattle on forages: efficiency of grazing management systems. J. Environ. Qual. 32: 267-277.

[10]Hales, K. E., N. A. Cole, and J. C. MacDonald. 2012. Effects of corn processing method and dietary inclusion of wet distillers grains with solubles on energy metabolism, carbon-nitrogen balance, and methane emissions of cattle. J. Anim. Sci. 90: 3174-3185.

[11]Hristov, A.N. 2012. Historic, pre-European settlement, and present-day contribution of wild ruminants to enteric methane emissions in the United States. J.Anim. Sci. 90:1371-1375.

For more information, contact:

National Cattlemen's Beef Association
Contractor to the Beef Checkoff Program
9110 East Nichols Avenue
Centennial, CO 80112
303.694.0305

Fact Sheet 18 in the Series: Tough Questions about Beef Sustainability

How does beef fit into a sustainable food system?

Sara E. Place, Ph.D., National Cattlemen's Beef Association

Much of the recent interest in sustainability regarding food is in response to a growing world population of increasing affluence that will lead to growth in global demand for food and animal protein specifically. Increases in food demand have led to concerns that we will be unable to meet the nutritional needs of future generations without causing serious environmental damage or exceeding the resource-carrying capacity of earth.[1]

The UN Food and Agriculture Organization defines a sustainable food system as "a food system that delivers food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition for future generations are not compromised."[2] Discussions related to the sustainability of our food system sometimes include arguments to reduce or abandon animal proteins with a particular focus on beef, because of its higher environmental footprint relative to other foods.[3, 4] While environmental footprints (e.g., water and carbon footprints) are useful tools to benchmark the sustainability of an individual food industry or commodity, like beef, they are also unable to capture all the relevant components of a sustainable food system.

Multiple factors important to a sustainable food system that are not captured in environmental footprints include:

1. Cattle can convert human-inedible feedstuffs into high quality human-edible protein.[5]

2. Cattle consume forages/roughages (high-fiber plant feeds) that are grown on lands unsuitable for cultivation, thereby expanding the land base available for food production.[6]

3. Cattle consume byproduct feeds from the food, fiber, and biofuels industries.[6]

4. Integrating cattle into row-crop plant agriculture systems (e.g., grazing corn stalks after harvesting corn, grazing winter wheat that is subsequently harvested for human-use grain) can have environmental and socioeconomic sustainability benefits.[7]

5. Beef cattle operations represent over 30% of the farms in the United States[8], and thus beef cattle producers play an important role in the agricultural economy and the social fabric of rural America.

The unique biology of cattle contributes both to beef's role in a sustainable food system and its environmental footprint.

Beef cattle are ruminant animals, which means they have a specialized stomach that contains four compartments. The largest of these compartments is called the rumen (hence, ruminants), which is home to trillions of microscopic bacteria, protozoa, and fungi. The trillions of microorganisms in the rumen of cattle and the host animal have a mutually beneficial relationship. The microbes are provided a warm, moist environment and a constant food supply from the feeds, enabling access to nutrients within the feeds that would otherwise be indigestible without the actions of the microorganisms.

Because of the unique biology of cattle, they fill an important role in our food system and the U.S. bio-economy by using human-inedible feeds or eating things that people cannot (**Figure 1**).[9] Human-inedible feeds for cattle include the plants cattle eat on range and pasture lands unsuitable for cultivated agriculture (e.g., the 770 million acres of rangeland[10] in the United States), and byproducts from the biofuels, fiber, and human food industries. By using byproducts that would otherwise go to waste, cattle are enhancing the sustainability of other industries. For example, cattle eat distillers grains from the corn ethanol industry, cottonseed that is a byproduct of cotton production, and beet pulp that is a byproduct of sugar beet production.

The relative difference in the human nutritional value of the feeds cattle eat versus the human nutritional value of beef can be substantial. This means cattle are acting as "upcyclers" in our food system: rather than simply recycling, cattle are upgrading human inedible plant proteins and food waste into high-quality protein and essential micronutrients, such as B vitamins. In some U.S. grain-finished beef production systems, more human-edible protein is generated in the form of beef than cattle consume in the form of feed (**Figure 2**).[6] Even when cattle are consuming human-edible feeds, such as corn grain, they are upgrading plant proteins to more complete and digestible proteins for humans. For example, the

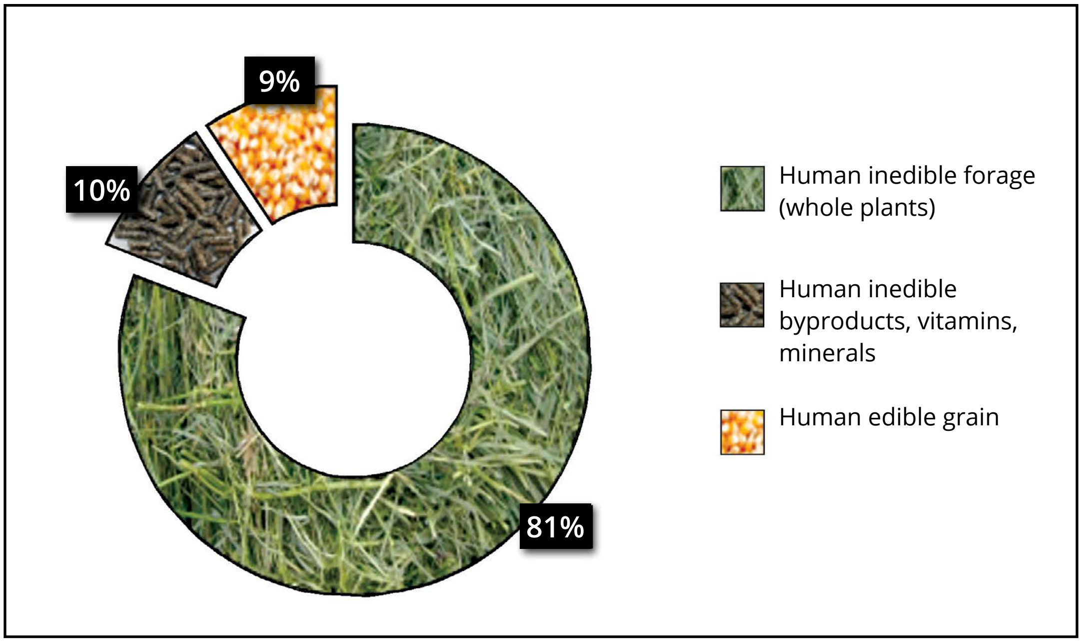


Figure 1. Life cycle feed intake of a grain-finished beef animal in the United States.[9] Over 90% of the lifetime feed intake of beef cattle is not in competition with the human food supply.

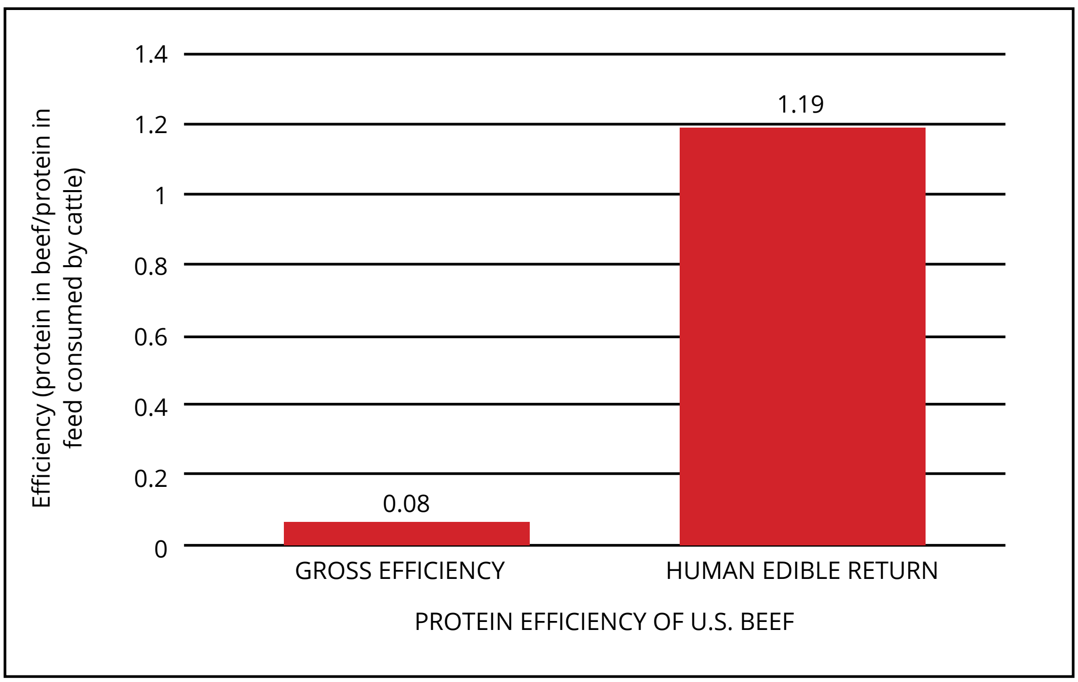


Figure 2. Efficiency of protein conversion by U.S. beef production expressed two ways.[6] Gross efficiency was calculated as outputs of human-edible protein in the form of beef divided by total protein feed inputs (i.e., no consideration given for if the protein in feed was human-edible, like corn, or inedible, like grass). Human-edible return was calculated as outputs of human edible protein in the form of beef divided by human-edible protein feed inputs. The value of 1.19 indicates more human-edible protein is returned from U.S. beef production than the beef cattle consume (i.e., beef cattle are a net source of protein to the human food supply).

digestible indispensable amino acid score of beef is 2.6 times greater than corn grain,[11] because the protein in beef is more bioavailable and contains a balance of the essential amino acids humans must consume in their diet.

One of the costs of the upcycling service provided by cattle is the production of methane from the rumen by microorganisms. Methane is a greenhouse gas 28 times more potent than carbon dioxide at trapping heat in the earth's atmosphere on a 100-year time scale.[12] The methane naturally released from the mouths of cattle, called enteric methane, contributes a substantial portion of the total greenhouse gas emissions produced by beef cattle. Enteric methane emissions make up 47% of the total carbon footprint of beef from grass-to-consumer's plate[13] and represent 1.8% of the total greenhouse gas emissions in the United States.[14] Improved production efficiency has increased the amount of beef produced per animal, and led to decreases in enteric methane emissions from beef cattle over time. Compared to 1975, enteric methane emissions from U.S. beef cattle were 34% lower[15] and U.S. beef production was 1% higher in 2014.[16] While researchers at Land Grant Universities are exploring ways to practically and cost-effectively further reduce natural emissions of enteric methane, it is important to recognize that methane production is the tradeoff of the sustainable service of upcycling that cattle provide.

***Bottom line:* Beef cattle play a unique role in a sustainable food system by upcycling – they consume plants and byproduct feeds of lower value and upgrade them to high-quality protein. Additionally, cattle can graze and consume feeds that are grown on land that is unsuitable for cultivation, thereby expanding the land base available for food production.**

References:

[1]Foley, J.A., N. Ramankutty, K.A. Brauman, E.S. Cassidy, J.S. Gerber, M. Johnston, N.D. Mueller, C. O'Connell, D.K. Ray, P.C. West, C Balzer, E.M. Bennett, S.R. Carpenter, J. Hill, C. Monfreda, S. Polasky, J. Rockström, J. Sheehan, S. Seibert, D. Tilman, and D.P.M. Zaks. Solutions for a cultivated planet. 2011. Nature. 478:337-342.

[2]HLPE. 2014. Food losses and waste in the context of sustainable food systems. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome, 2014.

[3]Eshel, G., A. Shepon, E. Noor, and R. Milo. 2016. Environmentally optimal, nutritionally aware beef replacement plant-based diets. Environ. Sci. Technol. 50:8164-8168.

[4]Clark, M. and D. Tilman. 2017. Comparative analysis of environmental impacts of agricultural production systems, agricultural input efficiency, and food choice. Environ. Res. Letters.12:064016.

[5]Oltjen, J.W. and J.L. Beckett. 1996. Role of ruminant livestock in sustainable agricultural systems. Journal of Animal Science. 74: 1406-1409.

[6]Council for Agricultural Science and Technology (CAST) 1999. Animal agriculture and global food supply. Task force report No. 135 July 1999, Department of Animal Science, University of California, Davis, CA, USA.

[7]Sulc, R.M. and A.J. Franzluebbers. 2014. Exploring integrated crop-livestock systems in different ecoregions of the United States. Europ. J. Agronomy. 57:21-30.

[8]USDA. 2014. 2012 Census of Agriculture. United States Summary and State Data. Available at: https://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_1_US/usv1.pdf (accessed August 17, 2017).

[9]National Academies of Sciences, Engineering, and Medicine. 2016. Nutrient Requirements of Beef Cattle, Eight Revised Edition. Washington, DC: The National Academies Press.

[10]Sustainable Rangelands Roundtable. 2008. Sustainable Rangelands Ecosystem Goods and Services. Available at: http://sustainablerangelands.org/pdf/Ecosystem_Goods_Services.pdf (accessed August 17, 2017).

[11]Ertl, P. W. Knaus, and W. Zollitsch. 2016. An approach to including protein quality when assessing the net contribution of livestock to human food supply. Animal. 10:1883-1889.

[12]Myhre, G., D. Shindell, F.-M. Bréon, W. Collins, J. Fuglestvedt, J. Huang, et al. 2013. Anthropogenic and natural radiative forcing. In: T.F. Stocker, D. Qin, G.-K. Plattner, M.M.B. Tignor, S.K. Allen, J. Boschung, et al., editors, Climate change 2013: The physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge Univ. Press, Cambridge, UK and New York. Available at: https://www.ipcc.ch/report/ar5/wg1/ (accessed 5 May 2017).

[13]Battagliese, T., J. Andrade, R. Vinas, K. Stackhouse-Lawson, C. A. Rotz, and J. Dillon. 2015. U.S. Beef – Phase 2 Eco-efficiency Analysis. http://www.beefresearch.org/CMDocs/BeefResearch/Sustainability%20Completed%20Project%20Summaries/BASF_NCBA%20US%20Beef%20Industry%20Phase2_%20NSF%20EEA%20Analysis%20Report_FINAL.pdf

[14]EPA. 2017. Inventory of U. S. Greenhouse Gas Emissions and Sinks: 1990-2015. U. S. Environmental Protection Agency, Washington, D. C.

[15]U.N. Food and Agriculture Organization. FAOSTAT Database – Food and agricultural data. Available at: http://www.fao.org/faostat/en/#home (accessed August 17, 2017).

[16]USDA NASS. 2017. Statistics by Subject. Available at: https://www.nass.usda.gov/Statistics_by_Subject/index.php?sector=ANIMALS & PRODUCTS (accessed August 17, 2017).

For more information, contact:

National Cattlemen's Beef Association
Contractor to the Beef Checkoff Program
9110 East Nichols Avenue
Centennial, CO 80112
303.694.0305

BEEF FACTS:
SUSTAINABILITY

BEEF
RESEARCH

Fact Sheet 19 in the Series: Tough Questions about Beef Sustainability

How does productivity affect sustainability?

Sara E. Place, Ph.D. National Cattlemen's Beef Association, a contractor to The Beef Checkoff

Productivity in agriculture can be defined as outputs per unit of input, with outputs including crop yields and animal protein production, and inputs including items like land and water. Over time, American agriculture has greatly increased its productivity, especially in the post-World War II era (**Table 1**).

Table 1. Productivity changes of U.S. corn and beef production from 1945 to 2016.[1]

Item	1945	2016	Percent Change
Corn, bushels per acre	33	175	+430%
Beef, lb beef per live animal	120	275	+129%

Data from USDA National Agriculture Statistics Service, 2018

How does productivity affect sustainability? Let's use the data in **Table 1** as an example. In 2016, the United States produced 25.2 billion pounds of beef and there were 92 million cattle (beef and dairy) on January 1st of that year. If we produced the same 25.2 billion pounds of beef in 2016 with 1945 efficiency, we would need a herd of 210 million beef and dairy cattle in the United States. What are the sustainability implications of 210 million vs. 92 million cattle? Even though the U.S. beef industry would still be providing the same amount of nourishment for people, we would have 118 million more cattle that would require feed and water, and beef production would likely generate more than twice the current amount of greenhouse gases.

Productivity improvements in plant and animal agriculture have worked together over time to reduce the amount of land and other natural resources required to produce animal protein. For example, U.S. beef's productivity improvements have occurred in part due to the development of the corn-finishing segment of the industry that confines cattle for the last 4 to 6 months of their life in a feedlot where they are fed a diet that typically includes 50 to 85% grain (usually, corn). Grain-finishing cattle can help increase the total beef produced per animal and shorten the time it takes from birth to harvest as compared to beef production systems that do not finish cattle with grain-based diets. (See Does grass-finished beef leave a lower carbon footprint than grain-finished beef?)*

The total amount of corn grain fed per pound of beef will vary across beef production systems, but it is close to 2.6 pounds of grain per pound of beef.[2] Using this ratio and given beef production in the United States in 2016, approximately 1.17 billion bushels of corn were required to produce beef. Considering 2016 average corn yields in bushels per acre, this was equivalent to 6.7 million acres of corn, which was 8% of harvested corn acres in 2016 or 0.3% of the land mass of the United States.[3]

However, if corn yields were at their 1945 levels, it would have required 35.6 million acres of corn – a 430% increase – to support U.S. grain-finished beef production. As this example illustrates, productivity improvements of plant and animal agriculture have worked together to reduce the amount of natural resources required to nourish people.

While a critique could be that agriculture now relies too much on inputs that may not be sustainable in the long-term (e.g., fossil fuels, synthetic N fertilizer) to achieve these productivity gains[4], the underlying increase in production has allowed more food to be produced now than in any other time in human history. According to the UN Food and Agriculture Organization, 31% more calories are available per person per day now than in 1961, despite the global population increasing by over 4 billion people.[5]

Continuing these productivity trends around the world is part of an effort called sustainable intensification, which aims to increase agriculture production per unit of input (land, water, etc.), while also paying attention to important sustainability issues like biodiversity, food security, and animal welfare.[6] Sustainably intensifying beef production around the world could dramatically reduce the number of cattle required to provide human nourishment and consequently the land, water, feed, and greenhouse gas emissions associated with producing beef globally.

For example, as is shown in **Figure 1**, the United States leads the world in beef system productivity. (See How does the carbon footprint of U.S. beef compare to global beef?)* Globally, 2.66 cattle are required and in Brazil 2.92 cattle are required to produce the same amount of beef associated with one animal in the United States. What does this mean for sustainability? Practically, these extra cattle required are analogous to idling cars and buses in our transportation system. They consume resources and produce pollution, yet they do not move anyone. Similarly, extra cattle create a burden on the natural environment, but do not provide human nourishment.

Why are there "extra cattle" around the world? It comes back to productivity. Other countries have beef systems that require more supporting cattle (cows, bulls, replacement heifers) due to poorer reproductive performance, herd health, genetics, and nutrition as compared to beef production in the United States. Additionally, cattle reach the point of harvest more quickly and at heavier body weights in the United States as compared to other countries around the world. Heavier body weights and shorter times to harvest translate into more beef produced per live animal. Beef per live animal should not be confused with beef per slaughtered animal, as beef per live animal encompasses the entire beef and dairy herd within a country rather than simply just the beef produced per each individual animal slaughtered. For example, the United States produced 275 pounds of beef per live animal in 2016, but produced an average of

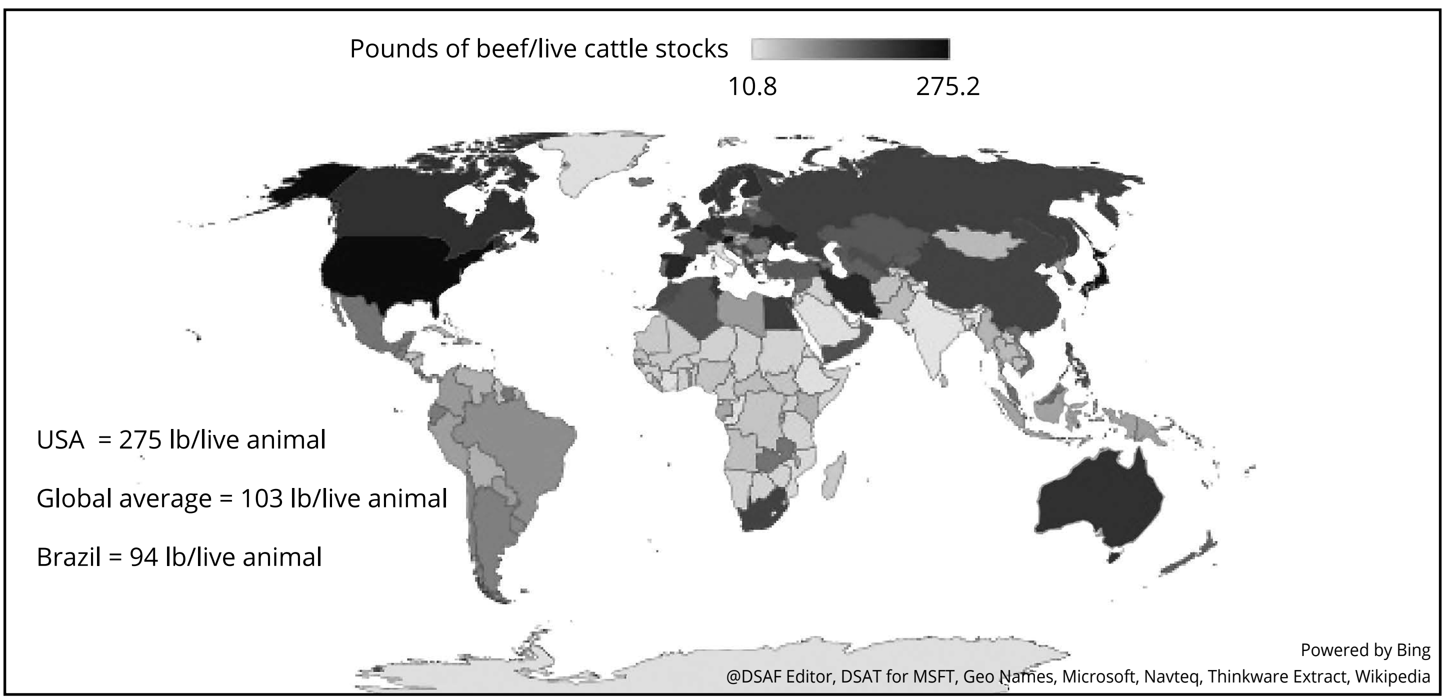


Figure 1. Pounds of beef produced per live cattle stocks by country across the world. "Live cattle stocks" refers to the number of beef and dairy animals in a country (including breeding stock) needed to produce the country's beef output. The United States leads the world in this productivity metric (275 lb/live animal); whereas, the second largest beef producing country in the world, Brazil, produces 94 lb/live animal. Brazil is less efficient today than the United States was in 1945. Data source: UN Food and Agriculture Organization.[5]

810 pounds of beef per slaughtered animal. What if the world could achieve current U.S. productivity levels? We would be able to produce the same amount of beef today with 975 million fewer cattle in the world. That's a 62% decline in the global cattle herd. Alternatively, we could double global beef production while still decreasing the global cattle herd by 25% (**Figure 2**).

consumption of animal-derived foods, such as beef, to reduce unwanted environmental impacts, like greenhouse gas emissions. However, most of these analyses ignore the dynamic nature of U.S. and global agriculture productivity changes and the fact that per capita consumption is a function of both food availability and population.

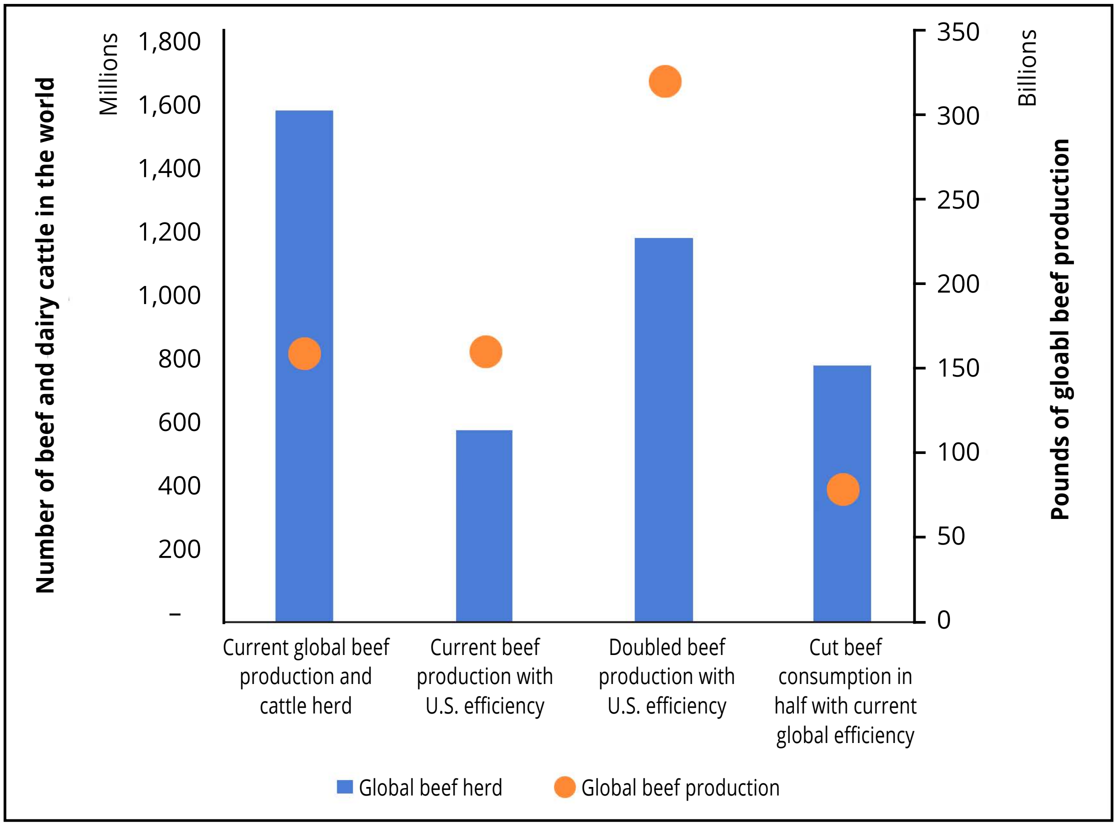


Figure 2. Global cattle herd and beef production for four scenarios: 1) current global beef production and cattle stocks, 2) producing current global beef production with U.S. efficiency across the world, 3) doubling global beef production with U.S. efficiency across the world, and 4) cutting beef production/consumption in half with current global beef production efficiency. Data source: UN Food and Agriculture Organization.[5]

Obviously, the beef production system that works best within the United States would likely not be perfectly translated to another part of the world; however, productivity outcome goals such as increasing the amount of beef produced per live animal are not prescriptive. Myriad ways likely exist for cattle producers to achieve better outcomes in countries like Brazil or China that do not need to completely emulate beef production practices within the United States.

Productivity is a powerful, but sometimes forgotten tool when it comes to sustainability. Many analyses of the U.S. and global food systems suggest reducing

Take for example scenario two in **Figure 2**: current global beef production with U.S. efficiency of production. In this case, the global cattle herd could shrink 62%, to 585 million cattle. We would assume this would also spare land resources, such as the Amazon rainforest in Brazil and reduce greenhouse gas emissions, because fewer cattle would be producing methane and manure, and fewer greenhouse gas emissions would be produced during the production of cattle feed. The percent reduction of greenhouse gas emissions would likely not be as great as the reduction in the number of cattle, but for simplicities sake in this thought experiment, let's say greenhouse gas emissions associated with beef production are cut in half.

What about an alternative of simply cutting beef consumption in half with current productivity (**Figure 2**)? If we cut current global beef production from 160 to 80 billion pounds, we would still require 780 million cattle in the world – a greater number than scenario two above. Thus, while we would also likely cut greenhouse gas emissions in this scenario, perhaps a bit less than half of today's emissions from global beef production, we would also cut the calories and nutrients supplied by beef in half. These calories and nutrients would need to be replaced by an alternative food item, and even if it is a food item with a lower greenhouse gas emissions intensity, there would still be additional greenhouse gas emissions produced. Thus, as this example illustrates, productivity is a sustainability tool that can allow us to reduce greenhouse gas emissions associated with beef or any other food item while maintaining or even increasing the calorie and nutrient supply available to humanity. We can cut greenhouse gas emissions from beef without cutting beef consumption. In the face of a growing population and increasing food demand, sustainable intensification is paramount.

Bottom line: Productivity is a powerful tool to improve the sustainability of food production, including beef, in the face of a growing population and increasing food demand. U.S. beef production is the most productive in the world, and the global impact of beef production could likely be dramatically reduced if other countries could achieve the same productivity as U.S. beef.

References

[1]USDA-NASS. 2018. Quick Stats. Available at: https://quickstats.nass.usda.gov/ Accessed February 16, 2018.

[2]Council for Agricultural Science and Technology (CAST) 1999. Animal agriculture and global food supply. Task force report No. 135 July 1999, Department of Animal Science, University of California, Davis, CA, USA

[3]USDA-ERS. 2018. Major Land Uses. Available at: https://www.ers.usda.gov/data-products/major-land-uses.aspx Accessed February 16, 2018.

[4]Pimentel, D. and M. Pimentel. 2003. Sustainability of meat-based and plant-based diets and the environment. Am. J. Clin. Nutri. 78:660S-663S.

[5]UN FAO. 2018. FAOSTAT. Available at: http://www.fao.org/faostat/en/#data Accessed February 16, 2018.

[6]Garnett, T., M. C. Appleby, A. Balmford, I. J. Batemane, T. G. Benton, P. Bloomer, B. Burlingame, M. Dawkins, L. Dolan, D. Fraser, M. Herrero, I. Hoffmann, P. Smith, P. K. Thorton, C Toulmin, S. J. Vermeulen, and H. C. J. Godfray. 2013. Sustainable intensification in agriculture: Premises and policies. Science. 341: 33-34.

*Website links found in this fact sheet are available at https://www.beefresearch.org/sustainability/index.html.

For more information, contact:

National Cattlemen's Beef Association
Contractor to the Beef Checkoff Program
9110 East Nichols Avenue
Centennial, CO 80112
303.694.0305