Cienc. Tecnol. Agropecuaria, *21* (3): e1524
DOI: https://doi.org/10.21930/rcta.vol21_num3_art:1524 ISSN: 0122-8706 ISSNe: 2500-5308

Environmental management and sustainability

Reflection article

Regarding some myths and realities about cattle livestock production

Juan Fernando Naranjo-Ramírez[1]*, Jhon Didier Ruiz-Buitrago[1]

[1] Universidad CES. Medellín, Colombia

* Corresponding author: Universidad CES. Medellín, Colombia. Calle 10ª #22-04. Edificio C, piso 3. Facultad de Medicina Veterinaria y Zootecnia. jnaranjo@ces.edu.co

Received: August 07, 2019
Accepted: April 24, 2020
Published: September 12, 2020

Subject editor: Sonia Daryuby Ospina Hernández (Corporación Colombiana de Investigación Agropecuaria [AGROSAVIA])

How to cite this article: Naranjo-Ramírez, J. F., & Ruiz-Buitrago, J. D. (2020). Regarding some myths and realities about cattle livestock production. *Ciencia y Tecnología Agropecuaria*, *21*(3), e1524. https://doi.org/10.21930/rcta.vol21_num3_art:1524

Abstract

The rise of cable television, the Internet, and the importance of social networks have contributed to the widespread dissemination of messages that are seriously affecting the agri-food system, mainly due to the dissemination of inaccuracies that create panic in some regions about the consumption of animal origin products. The collective imaginary is loaded with beliefs that, in most cases, do not have enough foundations and, in many others, it has a political sense or intentions without technical and scientific support. The aim of this document is to present evidence to support some myths related to bovine production systems to favor the debate on the consumption of beef, which is gaining strength around the world.

Keywords: cattle, environmental impact, food consumption, livestock production, sustainability

Sobre algunos mitos y realidades de la ganadería bovina

Resumen

El auge de la televisión por cable, el advenimiento de Internet y la expansión de las redes sociales han contribuido a que se difundan profusamente mensajes que están afectando en gran manera el sistema agroalimentario al difundir imprecisiones y generar, en algunas esferas, pánico hacia el consumo de productos de origen animal. El imaginario colectivo ha estado cargado de creencias que, en la mayoría de los casos, no tienen suficientes fundamentos y, en muchos otros, tienen un sentido político o intenciones sin sustento técnico ni científico. El objetivo de este documento es presentar elementos de juicio para examinar algunos mitos relacionados con los sistemas de producción bovina con el fin de aportar al debate sobre el consumo de este tipo de carne, que ha tomado fuerza alrededor del mundo.

Palabras clave: consumo de alimentos, ganado bovino, impacto ambiental, producción pecuaria, sostenibilidad

Introduction

In recent years, the message that the consumption of beef is harmful to health, and the environment has spread in different spheres of society (Carrington, 2018; Harrabin, 2018; Harwatt, 2018). The collective imagination has been loaded with beliefs that, in most cases, do not have sufficient foundations and, in many others, have a political sense or intentions without technical or scientific support. These are

inaccuracies and myths that build a movement that can become an enemy of the productive and social dynamics of the global agri-food system.

The sustainability of bovine production systems is often questioned by the environmental and social impacts attributed to it. However, livestock production is an indispensable and irreplaceable activity for the development of humanity. This article seeks to put into context some myths and realities associated with cattle farming by documenting different sources, evidence, and experiences that indicate that cattle farming can contribute to reversing some of the main effects of climate change on the planet, it strives to produce food of high biological value, safe and innocuous, and improve the quality of life of the people who depend on these production systems.

Social and economic importance of livestock

Human progress has depended on livestock products and services since at least the advent of agriculture (Food and Agriculture Organization of the United Nations [FAO], 2018). Different persons achieved food production at different times in prehistory as a result of the domestication of plants and animals. This production led some hunter-gatherer societies, characterized by being comprised of small and nomadic groups, to becoming numerous, sedentary, and stratified communities. As a consequence of the domestication of plants and animals, the excess of food generated the availability of more consumable calories and, therefore, led to population growth.

This food production was an indirect requirement for the development of civilization. Societies owning domestic animals such as livestock fed a higher number of people due to four main factors: milk and meat production, fertilizers, labor force, and transport (Diamond, 2007). Even the most modern post-industrial societies remain critically dependent on animals for their food and nutrition security. With the advance of understanding about economic development, progress must be made in recognizing the enduring importance of livestock, which is especially vital for the economies of developing countries, where food insecurity is a permanent concern (FAO, 2018).

The social and economic importance of cattle farming is undeniable. Globally, this activity involves about 1.3 billion producers and retailers and contributes to 40-50 % of the agricultural gross domestic product (GDP) (FAO, 2018). According to the Food and Agriculture Organization of the United Nations, the United States is the largest beef producer in the world (20 %), followed by Brazil (15 %) and the European Union (13 %); between the three they produce approximately 48 % of the beef consumed worldwide. Colombia is in 14th place in this classification, producing 1.34 % (825,000 MT) (FAO, 2020).

Regarding consumption, in 2018, the United States was the largest beef consumer in the world, followed by China and Brazil. In that year, the world population consumed 60.9 million metric tons of meat, of which 12 countries consumed more than one million. In the meat consumption ranking, Colombia is in the 15th position, with 1.21 % (739,000 MT).

In Colombia, livestock activity is also very important, since 623,794 farms are registered for livestock breeding, with 27.3 million cattle heads (Instituto Colombiano Agropecuario, 2019). Bovine livestock contributed 1.4 % of the gross national product (GNP) in 2017 and 21.8 % of the agricultural GNP.

Besides, it generated 6 % of the national employment and 19 % of the agricultural employment (Federación Colombiana de Ganaderos, 2018). Colombia has 34.4 Mha of pastures, of which 27.9 % are classified as unmanaged (Departamento Administrativo Nacional de Estadística, 2016).

The 2030 Agenda for Sustainable Development of the United Nations with its 17 Sustainable Development Goals (SDG) has become the framework approved by 169 countries around the world. The SDGs build on the success of the Millennium Development Goals 2000-2015 and aim to continue efforts to end poverty and hunger, by sustainably addressing the root causes of poverty and the global need for development. Livestock, being such an essential activity for humanity, has also been evaluated within the framework of the SDGs.

For decades, the debate in the livestock sector has focused on how to produce more with less to feed 9.8 billion people by 2050. However, the 2030 Agenda for Sustainable Development has broadened the discussion by shifting the focus from fostering sustainable livestock production *per se* to improve the contribution of the livestock sector to the achievement of the SDGs.

Along with enormous challenges, the future offers immense opportunities for the livestock sector, which can play a key role in improving the lives of millions of people. For this, an efficient and reliable supply of meat, milk, eggs, and dairy products must be ensured, and contribute to increasing the direct consumption of food of animal origin, which will generate jobs and strengthen the assets that rural households use to survive. Likewise, livestock can help improve the cognitive and physical development of children –and therefore their school performance–, contribute to the efficient use of natural resources, expand access to clean and renewable energy, support sustainable economic growth, generate large-scale income, create opportunities for value addition and industrialization, stimulate business among small farmers, close inequality gaps, promote sustainable consumption and production patterns, and increase household resistance to the climate crisis (FAO, 2018).

However, even though the critical role of this sector for world development is recognized, messages have been widely disseminated that attribute responsibility to livestock in deep-rooted problems of humanity and the need to stop consuming products of animal origin to adopt vegetarian and vegan habits (Willett et al., 2019). Thus, there is a series of myths about the production and consumption of beef, and the most commonly mentioned are the following:

- Cows are one of the main causes of global warming.
- Cows occupy agricultural land that could produce plant food.
- Livestock compete with humanity for food resources and are inefficient in converting food.
- Cows consume too much water.
- Vegetarian diets are better for the environment and do not affect human health.
- Livestock is the main responsible for the deforestation of the planet.
- Meat is full of antibiotics and hormones.

Although this list is not exhaustive, it documents the main myths that are widely disseminated, and that can be disputed from scientific and technical evidence to provide the general public with concrete evidence to facilitate responsible consumption decisions.

It is necessary to document and communicate that there are livestock production systems that are compatible with the SDGs and represent alternative models in line with the goal of producing more with less. These models generate development and quality of life for people who depend on livestock, do not alter agroecosystems significantly, and promote the ecological functionality of terrestrial systems by conserving or increasing natural capital.

Myth 1. Cows are one of the main causes of global warming

The documentary Cowspiracy (2019) and other similar sources that have become popular indicate that livestock is responsible for 51 % of all greenhouse gas (GHG) emissions in the world (Goodland & Anhang, 2009). In 2006, FAO stated that the livestock sector is an important factor in climate change, as it is responsible for 18 % of the GHGs measured in CO_2 equivalent, a much higher contribution compared to the transport sector (Cowspiracy, 2019; FAO, 2006). However, in 2013, FAO stated that an update of its inventories with another methodology suggested that emissions from livestock corresponded to 14.5 % of the global emissions (Gerber et al., 2013). Recently, the Environmental Protection Agency (EPA, 2019) reported in the United States GHG Emissions Inventory that agriculture contributes with 9 %, livestock with 4 %, and the meat production industry with 2 % of the total emissions of the country. These changes in the proportion of emissions are consistent with changes in the GHG metrics. Recent research indicates that estimates of the global warming potential of methane produced by livestock and other ruminants have been overestimated (Allen et al., 2018; Naranjo, 2019).

Myth 2. Cows occupy agricultural land that could produce plant food

The evidence contradicts this claim, since, in general, livestock inhabit lands where plants cannot be cultivated or at least not efficiently. Grasses, which are the main food of ruminants, have spread on the surface of the Earth due to their ability to adapt to environmental conditions that other plants cannot tolerate. Furthermore, "agricultural land" is not the same as "cultivation land"; land for cultivation is a portion of the agricultural land suitable for cultivation. Less than 4 % of the surface of the Earth is classified as suitable for cultivation, while almost a quarter is considered suitable for some forms of production with ruminant animals (Capper et al., 2013).

According to FAO (2018), about 50 % of the agricultural land in Latin America and the Caribbean is not suitable for cultivation and can only be used as grazing land (FAO, 1993). Thus, 4-6 times the amount of arable land can only be used in ruminant production systems. According to Eckelman and Sherman (2016), more than 85 % of the soil where cattle graze is not suitable for cultivation because it is too rocky, steep, or arid to support agricultural crops.

In the American tropic, approximately 60 % of the soils have some type of physical or chemical limitation that, in many cases, makes agriculture, not a viable option, which has favored their occupation by production systems with animal grazing (Gardi et al., 2014).

Currently, some approaches seek to organize the territory and the way to use the soils according to their agroecological suitability and capacities. For example, Andrade et al. (2018) suggest that areas suitable for livestock should be defined in Colombia according to biophysical limitations, which vary

from 10 % to 42 % of the total area currently used. In this sense, the Rural Agricultural Planning Unit (Unidad de Planificación Rural Agropecuaria, 2019) of Colombia has developed the Rural Agricultural Planning System (SIPRA, Sistema para la Planificación Rural Agropecuaria), a technological tool that allows knowing the agricultural potential of the country and planning the productive scenarios of entrepreneurship and innovation, to efficiently use and conserve natural resources.

Myth 3. Livestock compete with humanity for food resources and are inefficient in converting food

It is very common to hear this myth in both specialized and profane environments: the food that is given to livestock can be used to directly feed humans. The truth is that most livestock feed is not suitable for human consumption, not even for other animals. Ruminants are the only organisms on Earth that can process cellulose, the most widely distributed carbohydrate in nature. This ability is provided by its specialized stomach, which contains four compartments and is home to millions of bacteria, fungi, and protozoa that live in a symbiotic and beneficial relationship with the bovine. Evidence indicates that 86 % of the global livestock feed consumption consists of raw materials that are currently inedible by humans, including the leaves of grasses and other plants, forage crops, and crop residues (Mottet et al., 2017).

In contrast to the figures, it is commonly stated that 1 kg of meat requires 2.8 kg of edible feed for ruminants and 3.2 kg for monogastrics. However, the protein value of products derived from livestock is 19 % higher than the quality of the product ingested to produce this protein (Baber et al., 2018; Flachowsky et al., 2017). The production of bovine origin protein is highly efficient and can be considered as a food source of high biological value for humans. Since it requires pastures and forages not usable by humans and can be carried out on soils unsuitable for agricultural crops, bovine production constitutes an essential complement to food production for humans if it is done properly and in recommended places.

Myth 4. Cows consume too much water

A National Geographic publication stated that "beef is the king of large water footprints: it takes approximately 1,800 gallons of water to produce one pound of meat" (Madel & Olson-Sawyer, 2017). Analogous to the concept of ecological and carbon footprints, the water footprint is an indicator of water use in relation to consumer goods (Hoekstra, 2012). The water footprint is the volume of freshwater that is used to produce a product, measured in the different steps of the production chain. Water use is measured in terms of the volume of water consumed (evaporated) or contaminated.

The water footprint is classified by colors in blue, which is the volume of freshwater that evaporates from global blue water resources (surface and groundwater); green, which is the volume of water evaporated from global green water resources (rainwater stored in the ground), and gray, which is the volume of contaminated water and is quantified as the volume of water required to dilute pollutants to such an extent point that environmental water quality remains above the agreed water quality standards (Hoekstra, 2012).

The water footprint of any animal product is higher than the water footprint of a product grown in the soil, with an equivalent nutritional value. However, the majority (over 97 %) of the water footprint of livestock

is green. The water consumed by crops and livestock is not destroyed; it is recycled through the respiration of plants and animals and returns to the atmosphere in the form of water vapor. In Colombia, some studies that evaluate the water footprint in livestock have obtained results consistent with the literature (Martínez-Mamian et al., 2016; Romero et al., 2016). However, livestock activities should not be carried out in water sources and conservation areas to avoid affecting their cycle and the displacement of native fauna.

Myth 5. Vegetarian diets are better for the environment and do not affect human health

This myth has become popular with the recent publication of the EAT-Lancet Commission report (Willett et al., 2019), which suggests, in general terms, that plant-based diets would generate less environmental impact. The environmental footprint of animal feed production is considered several times higher than that of crops; therefore, the choice between animal and vegetarian diets can have a relevant environmental impact. In such comparisons, however, an often neglected issue is the nutritional value of foods.

Previous estimates of the environmental footprint of nutrients had been based, for the most part, on the raw weight of the food or its caloric content unrelated to human requirements. Essential amino acids are key parameters in the evaluation of food quality. When the environmental footprint is evaluated by comparing the amino acid content of foods with their requirements in humans, animal origin foods are favored (Tessari et al., 2016).

On the other hand, as has been suggested in some scenarios, if livestock were eliminated, the expansion of the agricultural frontier would be favored to cover food needs with products of less nutritional density (White & Hall, 2017). Appealing to this myth, the Mayor's Office of Medellín (Colombia) approved a rule to implement "Meatless Mondays" in public schools, without considering that this measure clearly violates some fundamental rights of children and adolescents enshrined in the Political Constitution of the country (Correa, 2018).

Food of animal origin have a higher content of true protein compared to plant origin food, and the biological value of animal protein is approximately 1.4 times higher than that of vegetable protein (Baber et al., 2018; Flachowsky et al., 2017). Furthermore, the quantity and quality of protein are believed to help regulate food intake in humans (and other animals) and reduce or control obesity (Simpson & Raubenheimer, 2005). Many essential minerals are not supplied by plant origin food due to their absence or low bioavailability (Ortega-Barrales & Fernández-de-Córdova, 2015), and the supply of antioxidants is higher in diets containing products of animal origin (Taubes, 2007).

If animal agriculture were eliminated in the United States, GHG emissions would be reduced by 2.60 % in the country, and by 0.36 % at the global level, with a considerable cost in the food balance of the population due to favoring essential dietary nutrient deficiencies (White & Hall, 2017). However, although livestock has an impact on GHG emissions, this is not of the magnitude that was previously estimated. Other sectors such as electricity, transport, and industry, in general, produced between 22 % and 29 % of the total GHG emissions in the United States during 2016 (EPA, 2019).

Although there are many investigations with arguments in favor and against diets with meat or vegetarian diets, there are no conclusive data, so the suggestion is to resort to all categories of nutrients and to bet on food alternation as a reasonable basis for healthy eating (Barbieri, 2017).

Myth 6. Livestock is the main responsible for the deforestation of the planet

This is probably the most misinformed myth of all. The dynamics of pastoral systems are driven by a complex combination of socio-economic, political, and environmental contexts. While the causes and dynamics can be highly location-specific, there are various explanations for each particular situation. Although grasslands have expanded worldwide in recent decades, a decreasing trend has been observed since the 21st century, mainly due to agricultural methods and techniques. For example, it is recognized that many cattle grazing-based production systems have been intensified in a sustainable way (Godde et al., 2018).

It is indisputable that livestock has been a factor causing deforestation in tropical America and mainly in Colombia; nonetheless, it has not been the only one. During the last 50 years, the transformation of tropical ecosystems, caused primarily by processes of deforestation and expansion of the agricultural frontier, has generated unprecedented impacts on biodiversity, climate, and other ecosystem phenomena. In Colombia, the leading causes of deforestation are the expansion of the agricultural frontier (especially for extensive cattle ranching), the planting of illicit crops, illegal logging, mining, infrastructure, forest fires, and population growth (González et al., 2011).

However, the livestock sector is taking action to reduce deforestation and increase forest cover. Since 2010, the World Bank, the Global Environment Facility (GEF), and the Department of Energy, Business and Industrial Strategy of the British Government have contributed economically so that 4,098 cattle farms become sustainable in Colombia. The Sustainable Colombian Livestock project includes stakeholders such as Federación Colombiana de Ganaderos (Fedegán), Centro para la Investigación en Sistemas Sostenibles de la Producción Agropecuaria (Cipav), Fondo para la Acción Ambiental y la Niñez (Fondo Acción), and The Nature Conservancy (TNC). The main objectives of the project are to increase the plant structure in livestock farms through the implementation of different agroforestry modalities, conserve and recover forests, and improve the ecological functionality indicators of livestock landscapes (Lerner et al., 2017).

In Brazil, the sustainable intensification of pasture areas has the potential to prevent further deforestation in the Amazon and generate social and environmental benefits (Garcia et al., 2017). For example, in the region of El Cerrado, sustainable intensification and forest protection have been achieved in the states of Rondônia and Mato Grosso (Pellegrino et al., 2018). Therefore, livestock production in producing countries must assume the role of economically, socially, and environmentally sustainable production to lead the recovery of the agricultural sector from the basic components of sustainability.

Myth 7. Meat is full of antibiotics and hormones

This myth has strong support in truthful information, but it requires some clarification. An estimated 700,000 people die each year from antimicrobial-resistant infections, and untold numbers of sick animals may not respond to treatment (FAO, 2017). Antimicrobial resistance is a significant global threat to public

health, food security, and food safety, as well as to life, animal production, and economic and agricultural development. The intensification of agricultural production has led to the increasing use of antimicrobials and this is expected to double by 2030. These drugs are essential for treating diseases in animals and plants, but they should be used responsibly and only when necessary.

Investment in good livestock practices that prioritize infection prevention and rational use should be made to stay ahead of antimicrobial resistance and keep it working effectively for as long as possible. For this, it is necessary to design adequate policies that support this type of practice. Adequate nutrition and health are fundamental human rights and critical factors in achieving the Zero Hunger SDG. For this reason, FAO works closely with the World Health Organization (WHO), the World Organisation for Animal Health (OIE), reference centers, academic circles, and regional groups on the Global Plan of Action on Resistance to Antimicrobials that apply the "One Health" approach and seek the solution to this problem comprehensively and effectively (WHO, 2016).

Since January 2017, the United States Food and Drug Administration (FDA) enacted regulations to decrease the use of medically important antibiotics in animal feed production systems (Tang et al., 2017). Veterinary oversight of antibiotic use is critical to the new regulations. In the United States, drugs previously available over-the-counter can now be purchased only with a written prescription from a licensed veterinarian (Tang et al., 2017). Since these regulations went into effect, pharmaceutical companies that produce these drug compounds have suffered marked drops in demand for their products. Meat suppliers and retailers have announced deadlines for purchasing antibiotic-free products. Besides, the leading meat producers have developed strategies to reduce the use of antibiotics. For years, probiotics, plant extracts, and other compounds have been used with success in some livestock systems and succeeded in replacing some antimicrobials.

Conversely, hormones are chemical messengers produced by the body that travel through the bloodstream to regulate bodily functions such as reproduction, metabolism, and growth. For decades, growth implants based on steroids, with estrogenic (estradiol or zeranol), androgenic (testosterone acetate or trenbolone), or a combination of these compounds have been used. Steroidal implants stimulate feed intake and protein deposition, and have a profound impact on livestock performance and feed utilization efficiency.

The use of steroids covers the production, growth, and finishing phases and is very widespread in confinement systems and feedlots. These are very popular in countries like the United States, but very little in tropical regions or in grazing meat production systems. Its application has decreased with the rise of organic and natural production systems, and many markets already require a non-use guarantee (Drouillard, 2018). In this sense, certifications such as Good Livestock Practices (BPG) required by Fedegán seek to provide consumers with a warranty regarding the quality and safety of these types of products.

Conclusions

Rather than trying to defend livestock farming *per se* and promote the consumption of animal origin products, this reflection seeks to highlight good practices and show that alternative forms of livestock farming are possible and ongoing. Although the contribution of livestock production to GHG emissions

is recognized, its potential to develop mitigation and adaptation strategies to global climate change is also documented. In recent years, different international initiatives have emerged such as LivestockPlus from the International Center for Tropical Agriculture (CIAT), Grupo de Trabalho da Pecuária Sustentável (GTPS) from Brazil, the ENOUGH movement (focused on four pillars: innovation, choice, access, and nutrition), the climate-smart agriculture approaches, and FAO's sustainable intensification strategies. In Colombia, the Sustainable Colombian Livestock initiative (Ganadería Colombiana Sostenible) and the national and regional experiences of the Sustainable Livestock Board (Mesa Ganadera Sostenible) stand out. These have promoted the concept of green and inclusive growth in academic, regional, and international political spheres, and whose conceptualization is still the subject of debate.

Sustainable and climate-compatible livestock farming seeks to develop and implement strategies for the sustainable productive intensification and environmental responsibility to demonstrate that in the tropics, improved forages can lead to the sustainable intensification of mixed production systems. These systems integrate forages and crops or trees to produce multiple social, economic, and environmental benefits. Sustainable intensification not only increases the productivity of tropical forage-based systems, but also reduces the ecological footprint of livestock production and generates a variety of ecosystem services, such as improved soil quality, reduced erosion and sedimentation, and mitigation of GHG emissions. These good livestock practices, which include the proper management of soils, pastures, supplements, animals, machinery, personnel, and associated technologies, represent safe ways to increase productivity and reduce the environmental impacts of livestock because, even though this activity is considered by many to be the main responsible for global climate change, under a sustainable livestock approach it is the productive activity with the highest mitigation potential worldwide.

Sustainability is not a destination; it is a continuous journey made by every generation of farmers and ranchers responsible for raising and supplying meat around the world. For the beef community, sustainability encompasses much more than environmental considerations. Today, livestock activity is a source of sustainable food that balances efficient production with environmental, social, and economic impacts; a parameter that should govern the development of future livestock.

Acknowledgments

The authors thank Facultad de Medicina Veterinaria y Zootecnia of Universidad CES for providing the logistical and economic support to prepare this document, as well as the project "Resilient agricultural systems in the humid tropics for post-conflict rurality" through the Colciencias call 745 - For CTeI projects and their contribution to the country's challenges, 2016.

Disclaimers

The authors made significant contributions to the document, agree with its publication, and state that there are no conflicts of interest in this manuscript.

References

Allen, M., Shine, K., Fuglestvedt, J., Millar, R., Cain, M., Frame, D., & Macey, A. (2018). A solution to the misrepresentations of CO_2-equivalent emissions of short-lived climate pollutants under ambitious mitigation. *npj Climate and Atmospheric Science, 1*, 16. https://doi.org/10.1038/s41612-018-0026-8

Andrade, G., Chaves, M., Corzo, G., & Tapia, C. (2018). *Transiciones socioecológicas hacia la sostenibilidad. Gestión de la biodiversidad en los procesos de cambio de uso de la tierra en el territorio continental colombiano*. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt. http://hdl.handle.net/20.500.11761/35145

Baber, J., Sawyer, J., & Wickersham, T. (2018). Estimation of human-edible protein conversion efficiency, net protein contribution, and enteric methane production from beef production in the United States. *Translational Animal Science, 2*(4), 439-450. https://doi.org/10.1093/tas/txy086

Barbieri, A. (2017, February 24). ¿Quién vive más, los que comen carne o los que no? *La Vanguardia*. https://bit.ly/2AXK4Lc

Capper, J., Berger, L., Brashears, M., & Jensen, H. (2013). Animal feed vs. human food: challenges and opportunities in sustaining animal agriculture toward 2050. *Economics Technical Reports and White Papers, 16*. http://lib.dr.iastate.edu/econ_reportspapers/16

Carrington, D. (2018, October 10). Huge reduction in meat-eating 'essential' to avoid climate breakdown. *The Guardian*. https://bit.ly/32e9sYp

Correa, H. J. (2018). "Día sin Carne" en la ciudad de Medellín: aspectos constitucionales. *CES Medicina Veterinaria y Zootecnia, 13*(2), 184-192. http://dx.doi.org/10.21615/cesmvz.13.2.7

Cowspiracy. (2019). *The facts*. http://www.cowspiracy.com/facts

Departamento Administrativo Nacional de Estadística. (2016). *Censo Nacional Agropecuario 2014*. https://bit.ly/2ZWfyKn

Diamond, J. (2007). *Armas, gérmenes y acero. Breve historia de la humanidad en los últimos 13000 años*. DeBolsillo.

Drouillard, J. (2018). Current situation and future trends for beef production in the United States of America - A review. *Asian-Australasian Journal of Animal Sciences, 31*(7), 1007-1016. https://doi.org/10.5713/ajas.18.0428

Eckelman, M., & Sherman, J. (2016) Environmental impacts of the U. S. health care system and effects on public health. *PLoS One, 11*(6), e0157014. https://doi.org/10.1371/journal.pone.0157014

Environmental Protection Agency. (2019). *Inventory of U. S. Greenhouse Gas Emissions and Sinks. 1990-2017*. https://bit.ly/2ZqPtnm

Federación Colombiana de Ganaderos. (2018). *Ganadería colombiana. Hoja de ruta 2018 - 2022*. https://bit.ly/3jdOGye

Flachowsky, G., Meyer, U., & Südekum, K. H. (2017). Land use for edible protein of animal. *Animals, 7*(3), 25. https://doi.org/10.3390/ani7030025

Food and Agriculture Organization of the United Nations [FAO]. (1993). Las tierras de pastoreo y su importancia. En *Papel del ganado doméstico en el control de la desertificación*. http://www.fao.org/3/X5320S/x5320s03.htm

Food and Agriculture Organization of the United Nations [FAO]. (2006). *Livestock's long shadow. Environmental issues and options*. http://www.fao.org/3/a0701e/a0701e.pdf

Food and Agriculture Organization of the United Nations [FAO]. (2017, November 14). *Antimicrobial resistance - What you need to know*. http://www.fao.org/fao-stories/article/en/c/1056781/

Food and Agriculture Organization of the United Nations [FAO]. (2018). *World Livestock. Transforming the livestock sector through the Sustainable Development Goals*. http://www.fao.org/3/CA1201EN/ca1201en.pdf

Food and Agriculture Organization of the United Nations [FAO]. (2020). *FAOSTAT. Ganadería* [dataset]. http://www.fao.org/faostat/es/#data/QA

Garcia, E., Ramos Filho, F. S. V., Mallmann, G. M., & Fonseca, F. (2017). Costs, benefits and challenges of sustainable livestock intensification in a major deforestation frontier in the Brazilian Amazon. *Sustainability, 9*(1), 158. https://doi.org/10.3390/su9010158

Gardi, C., Angelini, M., Barceló, S., Comerma, J., Cruz Gaistardo, C., Encina Rojas, A., Jones, A., Krasilnikov, P., Mendonça Santos Brefin, M., Montanarella, L., Muñiz Ugarte, O., Schad, P., Vara Rodríguez, M., & Vargas, R. (2014). *Atlas de suelos de América Latina y el Caribe*. Comisión Europea, Unión Europea. http://dx.doi.org/10.2788/37334

Gerber, P. J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., Falucci, A., & Tempio, G. (2013). *Tackling climate change through livestock. A global assessment of emissions and mitigation opportunities*. Food and Agriculture Organization of the United Nations. http://www.fao.org/3/a-i3437e.pdf

Godde, C., Garnett, T., Thornton, P., Ash, A., & Herrero, M. (2018). Grazing systems expansion and intensification: drivers, dynamics, and trade-offs. *Global Food Security, 16*, 93-105. https://doi.org/10.1016/j.gfs.2017.11.003

González, J. J., Etter, A. A., Sarmiento, A. H., Orrego, S. A., Ramírez, C., Cabrera, E., Vargas, D., Galindo, G., García, M. C., & Ordoñez, M. F. (2011). *Análisis de tendencias y patrones espaciales de deforestación en Colombia*. Instituto de Hidrología, Meteorología y Estudios Ambientales. https://bit.ly/2CBW31k

Goodland, R., & Anhang, J. (2009). Livestock and climate change. What if the key actors in climate change are… cows, pigs, and chickens? *World Watch, 22*(6), 10-19. https://bit.ly/30c2yA5

Harrabin, R. (2018, November 15). Climate change: report says 'cut lamb and beef'. *BBC News*. https://www.bbc.com/news/science-environment-46214864

Harwatt, H. (2018). Including animal to plant protein shifts in climate change mitigation policy: a proposed three-step strategy. *Climate Policy, 19*(5), 533-541. https://doi.org/10.1080/14693062.2018.1528965

Hoekstra, A. Y. (2012). The hidden water resource use behind meat and dairy. *Animal Frontiers, 2*(2), 3-8. https://doi.org/10.2527/af.2012-0038

Instituto Colombiano Agropecuario. (2019). *Censo pecuario año 2019*. https://bit.ly/30986vf

Lerner, A. M., Zuluaga, A. F., Chará, J., Etter, A., & Searchinger, T. (2017). Sustainable cattle ranching in practice moving from theory to planning in Colombia's livestock sector. *Environmental Management, 60*(2), 176-184. https://doi.org/10.1007/s00267-017-0902-8

Madel, R., & Olson-Sawyer, K. (2017, December 26). How water footprints can help us eat less water. *National Geographic*. https://bit.ly/3fzHv0Y

Martínez-Mamian, C. A., Ruiz-Erazo, X. A., & Morales-Velasco, S. (2016). Huella hídrica de una finca ganadera lechera bajo las condiciones agroecológicas del Valle del Cauca. *Biotecnología en el Sector Agropecuario y Agroindustrial, 14*(2), 47-56. https://doi.org/10.18684/BSAA(14)47-56

Mottet, A., Haan, C., Falcucci, A., Tempio, G., Opio, C., & Gerber, P. (2017). Livestock: on our plates or eating at our table? A new analysis of the feed/food debate. *Global Food Security, 14*, 1-8. https://doi.org/10.1016/j.gfs.2017.01.001

Naranjo, J. F. (2019). En defensa del metano (de las vacas). *CES Medicina Veterinaria y Zootecnia, 14*(2), 80-86. http://dx.doi.org/10.21615/cesmvz.14.2.7

Ortega-Barrales, P., & Fernández-de-Córdova, M. (2015). Meat. En M. de la Guardia & S. Garrigues (Eds.), *Handbook of mineral elements in food* (pp. 599-619). John Wiley & Sons.

Pellegrino, C. E., Clemente, C., Ferreira, S. M., Cherubin, M. R., Feigl, B., & Lal, R. (2018). Reducing Amazon deforestation through agricultural intensification in the Cerrado for advancing food security and mitigating climate change. *Sustainability, 10*(4), 989. https://doi.org/10.3390/su10040989

Romero, M., Quintero, M., & Monserrate, F. (2016). *Elementos técnicos para la medición de huella hídrica en sistemas agrícolas*. Centro Internacional de Agricultura Tropical.

Simpson, S. J., & Raubenheimer, D. (2005). Obesity: the protein leverage hypothesis. *Obesity Reviews, 6*(2), 133-142. https://doi.org/10.1111/j.1467-789X.2005.00178.x

Tang, K., Caffrey, N., Nóbrega, D., Cork, S., Ronksley, P., Barkema, H., Polachek, A., Ganshorn, H., Sharma, N., Kellner, J., & Ghali, W. (2017). Restricting the use of antibiotics in food-producing animals and its associations with antibiotic resistance in food-producing animals and human beings: a systematic review and meta-analysis. *The Lancet Planetary Health, 1*(8), E316-E327. https://doi.org/10.1016/S2542-5196(17)30141-9

Taubes, G. (2007). *Good calories, bad calories. Challenging the conventional wisdom on diet, weight control, and disease*. Alfred Knopf.

Tessari, P., Lante, A., & Mosca, G. (2016). Essential amino acids: master regulators of nutrition and environmental footprint? *Scientific Reports, 6*, 26074. https://doi.org/10.1038/srep26074

Unidad de Planificación Rural Agropecuaria. (2019). Sistema para la Planificación Rural Agropecuaria. https://sipra.upra.gov.co/

White, R. R., & Hall, M. B. (2017). Nutritional and greenhouse gas impacts of removing animals from US agriculture. *PNAS, 114*(48), E10301-E10308. https://doi.org/10.1073/pnas.1707322114

Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, P. T., Vermeulen, S., Garnett, T., Tilman, D., DeClerck, F., Wood, A., Jonell, M., Clark, M., Gordon, L., Fanzo, J., Hawkes, C., Zurayk, R., Rivera, J., De Vries, W., Sibanda, L... Murray, C. J. (2019). Food in the anthropocene: the EAT–*Lancet* Commission on healthy diets from sustainable food systems. *The Lancet Commissions, 393*(10170), 447-492. https://doi.org/10.1016/S0140-6736(18)31788-4

World Health Organization [WHO]. (2016). *Plan de acción mundial sobre la resistencia a los antimicrobianos*. https://bit.ly/2WBn38H