# Sustaining rangelands in the 21st century

By Nathan F. Sayre

## On the Ground

- The major threats to sustaining rangelands in the 21st century are climate and land-use change, both of which originate outside of rangelands themselves.
- Society's demands on rangelands have shifted away from livestock production and toward services and disservices such as climate mitigation and greenhouse gas emissions.
- Sustaining rangelands in the United States depends on sustainability of the larger beef production system, including crop agriculture, feeding, and finishing.
- Understanding the history of the beef system helps identify strategies and priorities for sustaining rangelands and meeting society's evolving demands.

**Keywords:** sustainability, beef production, climate change, land-use change, feedlots.

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Sustaining rangelands has been central to the mission of SRM from its foundation nearly 75 years ago. But the meaning of sustainability has evolved with changes in our knowledge, in rangelands, and in society's concerns and demands. Historically, the primary focus was on uses and products such as forage, water, wildlife, forestry, and recreation. This prioritized the art and science of range management, applied on rangelands, with livestock grazing as a core concern in most cases. If sustainability were still just a question of how to manage livestock grazing, I think we could say we know how to do that pretty well by now. It's not easy, but it's also not a mystery—and it is still important. Society's concerns continue to evolve, however, and many people now see the value of rangelands through the lens of global issues such as biodiversity, energy, and climate. This is not just a demand for different products. Rather, people are asking about services and disservices—how rangelands contribute to global problems and needs.[1]

This effectively means sustaining rangelands in the 21st century depends on what happens in other places. The biggest threats to rangelands (and the services they provide) are climate and land-use change, both of which originate elsewhere.[2,3] Modern society has long seen rangelands as a reserve supply of "under-employed" land available for other uses as they arise; livestock grazing, on this view, is just a placeholder until something more lucrative or urgent comes along. Simply put, land-use change is lucrative and climate change is urgent; the recent rapid expansion of solar and wind energy production on rangelands is evidence of both.[4]

Sustaining rangelands thus poses a dilemma. On one hand, livestock grazing is still the activity that stands the best chance of preventing land-use change on extensive grazing lands while supporting people in the face of a changing climate. On the other hand, there is widespread belief, at least in the wealthier parts of the world today, that livestock production is inherently unsustainable due to greenhouse gas (GHG) emissions and other environmental impacts. A growing chorus of environmentalists, scientists, philanthropists, and entrepreneurs is demanding radical transformation—or outright elimination—of animal-based meat production as a whole.[5,6] Notably, the art and science of range management is largely irrelevant to these demands. How should range scientists and the SRM respond?

In the face of this dilemma, sustaining rangelands depends on the sustainability of beef production as a whole, because the beef system determines both the economic viability of livestock production and how rangelands are framed in climate debates. Rangelands are only one piece of this system, which also encompasses sown pastures and croplands producing various feedstuffs and byproducts that cattle consume; the feedlots and processing plants where cattle are finished and slaughtered; and the supply chains and infrastructures supporting the whole system. Notably, much of the land involved is former rangeland. Unfortunately, very little literature spans rangelands and the rest of the beef system.[7,8]

I explore the interdependency of rangelands and the beef system to draw out lessons for the present century. At the



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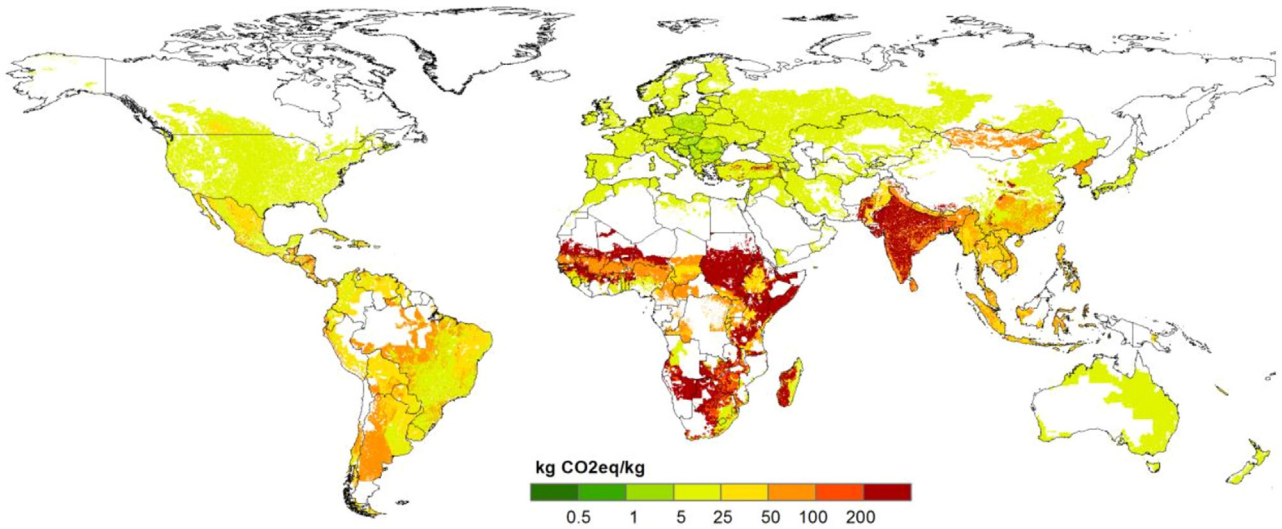


**Figure 1.** Greenhouse gas efficiency of bovine meat production in the year 2000, expressed in kg $CO_2$eq/kg product.[8] Emissions per unit of meat vary widely, largely due to lifespans; cattle in the developed world grow more quickly and are slaughtered at a younger age.

center of the story is the feedlot and the practice of fattening (or "finishing") livestock on grains such as corn or other crop-based feeds. The feedlot is the quintessence of modern livestock production: a marvel of industrial efficiency for supporters and the embodiment of its ills for detractors. Where did the feedlot originate? How has it affected rangelands and range livestock production? What can be learned from this history? Although my focus is primarily the United States, the answers to these questions are also relevant to rangelands in other parts of the world.

Both globally and in the United States, beef production is extraordinarily varied and complex, with environmental impacts as diverse as the landscapes, breeds, and production systems involved.[9,10] Averaged worldwide, producing 100 g of beef protein results in 25 kg of $CO_2$ equivalent, but this masks more than an order of magnitude difference between the 10th percentile (9 kg $CO_2$eq) and the 90th (105 kg).[11] More so than for other foods, GHG emissions per unit of output varies widely between countries and regions (Fig. 1), and even between firms in the same country. Other impacts of beef production are geographically uneven as well. Brazilian beef is exported primarily to the Middle East and Asia, for example; very little of it goes to North America. Thus, if Americans stopped eating beef, it would have virtually no effect on Amazonian deforestation.[12]

Livestock production in the developed world actually reduced its GHG emissions from 1960 to 2010, and the United States is among the lowest intensity producers in the world.[13] The primary reasons are high-quality forages and feeds, livestock breeds that optimize these feeds, and high reproduction and growth rates. Taken together, these factors reduce the average lifespan of beef cattle, maximize output per unit of biomass, water and time, and thereby minimize emissions. How this came about holds a number of important lessons for sustaining rangelands in the 21st century.

Modern, industrial-scale feedlots developed after World War II, but their predecessors date back to the early 1800s when Euro-American settlers colonized the rich farm lands of the Ohio River Valley. Their fields yielded bountiful harvests when planted with corn, a cultivar adopted from Native Americans. But transportation was too expensive to justify hauling their crops to markets over the Appalachians to the east or far downriver to New Orleans. Instead, they fed the corn to pigs and cattle, which could carry themselves to market.

The feedlot was invented on these Ohio Valley farms. Mature corn plants—stalks, leaves, and ears-in-the-husk—were cut and piled into stacks, called "shocks," that dotted the fields after harvest. As historical geographer John Hudson[14] explains:

> *A ten-acre cornfield was the basic unit, supporting one hundred head of cattle in the late fall fattening season. Twelve to sixteen hills of corn were gathered to provide one shock; one-half bushel of shock corn per head per day was fed from early November to February, when the drive to market began. For each field there were two or three of like size adjoining it, filled with the same arrangement of corn in the shock, through which the animals were changed to fresh lots at every feed, morning and evening. Each lot of one hundred head was fed together and then driven to market together.* (p.71)

The key innovation was feeding the animals in the fields, where their manure would replenish the fertility of the soil:

> *Feedlots eliminated cattle barns. The considerable amount of corn that passes whole through a steer becomes unusable waste when produced by an animal fed in a barn stall, but in a feedlot that corn becomes accessible feed for hogs. Between one hundred and two hundred hogs cleaning up after corn-fed steers could be fattened simply on the waste. The manure produced both by cattle and hogs enriched the soil of the series of fields through which they were rotated in the feeding season, providing nutrients for the next year's crop.* (p.71)



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By 1840, pig processing had become a major industry in Cincinnati, Ohio, giving rise to some of the world's first large-scale slaughterhouses. After the Civil War, the center of meat processing shifted from Cincinnati to Chicago, linked via the railroads to markets in the East, and the feedlot model expanded to encompass a vastly larger geography. Pioneer cattleman and booster Joseph McCoy[15] wrote in 1873 that, "Central Illinois has become universally wealthy by corn raising and hog and cattle feeding, or, in other words, making the live stock product of other regions fit for eastern markets and consumption" (p.166). Settlers borrowed money to buy and improve land, and as land values rose, farmers planted ever more corn to cover their debts; as more and more land was plowed, cattle were pushed further west.[16] Thus, a gigantic geographical division of labor was established between the Union Stock Yards in Chicago, farms in the emerging Corn and Wheat Belts, and ranches on the semiarid rangelands of the High Plains and Southwest.

With demand for beef booming at home and abroad, the last third of the 19th century witnessed breakneck change on the Great Plains. Bison (*Bison bison*) were hunted nearly to extinction, Native Americans were dispossessed and confined to reservations, and vast areas of prairie were plowed up and converted to croplands. Productivity gains in agriculture were huge, but industrialization produced even greater gains in the rest of the economy, so farmers and ranchers prospered. Historian Richard White[17] explains:

> *In this new economic world of increased demand and increased production a seeming miracle occurred: western farmers received a higher real price for their wheat even as eastern consumers paid less for it. The price of wheat on the world market fell during the late nineteenth century, but in real terms (that is, in terms of actual buying power) farmers received more for their crop than ever before. The source of this seeming paradox lay in declining transportation costs, declining production costs, and declines in the prices of goods purchased by farmers.* (p.245)

The advent of feedlots had significant ramifications for rangelands.[16] As already suggested, profits from corn feeding drove conversion of prairies from rangelands into croplands (more on this below). Feeding also gave ranchers a reliable outlet for their animals, allowing them to destock for the winter or when range forage was depleted. Most importantly, feedlots helped drive a change in the livestock themselves. British livestock breeds, such as the Shorthorn, Durham, Hereford, and Angus, had been bred specifically for rapid growth when fed on fodder crops and sown pastures, and their meat fetched a premium for its higher fat content and marbling. From the 1870s onward, under pressure from farmer-feeders (who were responding to pressure from meatpackers), cattle producers began crossing British breeds with the Longhorns that had spread from Texas in the famous cattle drives. The newer breeds were not well suited to the dry rangelands of the West, but they thrived on corn when transferred to Midwestern farms.

Range science, and the system of public land tenure and administration we associate with the Western Range, was conceived in response to this period of breakneck change, in particular the devastation that resulted when severe winter storms and droughts in the 1880s and 1890s led to massive cattle die-offs and overgrazing (probably made worse by the shift to British breeds). Not surprisingly, range science focused on the range portion of the production cycle, leaving the rest to other disciplines such as agronomy and animal science.[18] This has obscured the fact that ranching, corn farming, and grain-finishing coevolved together. In a very real sense, there has never been ranching in the United States without corn feeding as the next step in the production of beef.

To put this history in a longer-term perspective, I should note that in 1492 there were an estimated 405 million hectares (1 billion acres) of rangeland in what is now the United States. Since then, a little more than one-third of that area (139 million hectares [343 million acres]) has been converted to other land cover types and thereby lost as rangelands (Fig. 2).[19] These figures are probably under-estimates. There is evidence that significant savannas were found east of the Mississippi: bison were found as far east as New York, for example, and the long-leaf pine (*Pinus palustris*) forests of the southeastern coastal plains were savannas at the time of contact. It is now recognized that Native Americans produced these savannas, which have largely filled in with trees due to the removal of Indigenous burning.[20] Historians also note that when Europeans first landed in North America, from New England to the Gulf of Mexico, they remarked on the abundance of pastures suitable for their cattle and other livestock, which were instrumental to the success of colonization and settlement throughout the Americas.[21]

Because homesteaders gravitated toward the more productive areas—generally those best suited to cultivation—these are now primarily private lands, and the most productive are no longer rangelands at all.[22] An estimated 98% of the tall grass prairie and 67% of the midgrass prairie is gone.[23] The Palouse prairie of the Pacific Northwest is almost entirely cropped, as are large parts of the San Joaquin, Salinas, and Imperial valleys in California. Conversion of private rangelands to cultivated agriculture continues to this day—a little more than 810,000 hectares (2 million acres) in 12 midwestern states between 2008 and 2016.[24] Private rangelands are susceptible to conversion to other uses, as well, such as residential or energy development. This is important not only for rangeland ecosystems and their biota, but also for climate change. Rangelands contain approximately 30% of the world's soil carbon, and an estimated 45% of cattle-related GHG emissions worldwide are attributable to land-use change (e.g., Amazonian deforestation). Restoring cultivated lands to rangeland would sequester significant amounts of carbon, and avoiding the loss of carbon from rangeland soils is probably the most effective strategy for climate change mitigation involving rangelands going forward.[25-27]

In other words, anyone concerned about the sustainability of rangelands today needs to be concerned about former rangelands as well as those that remain. US beef production is



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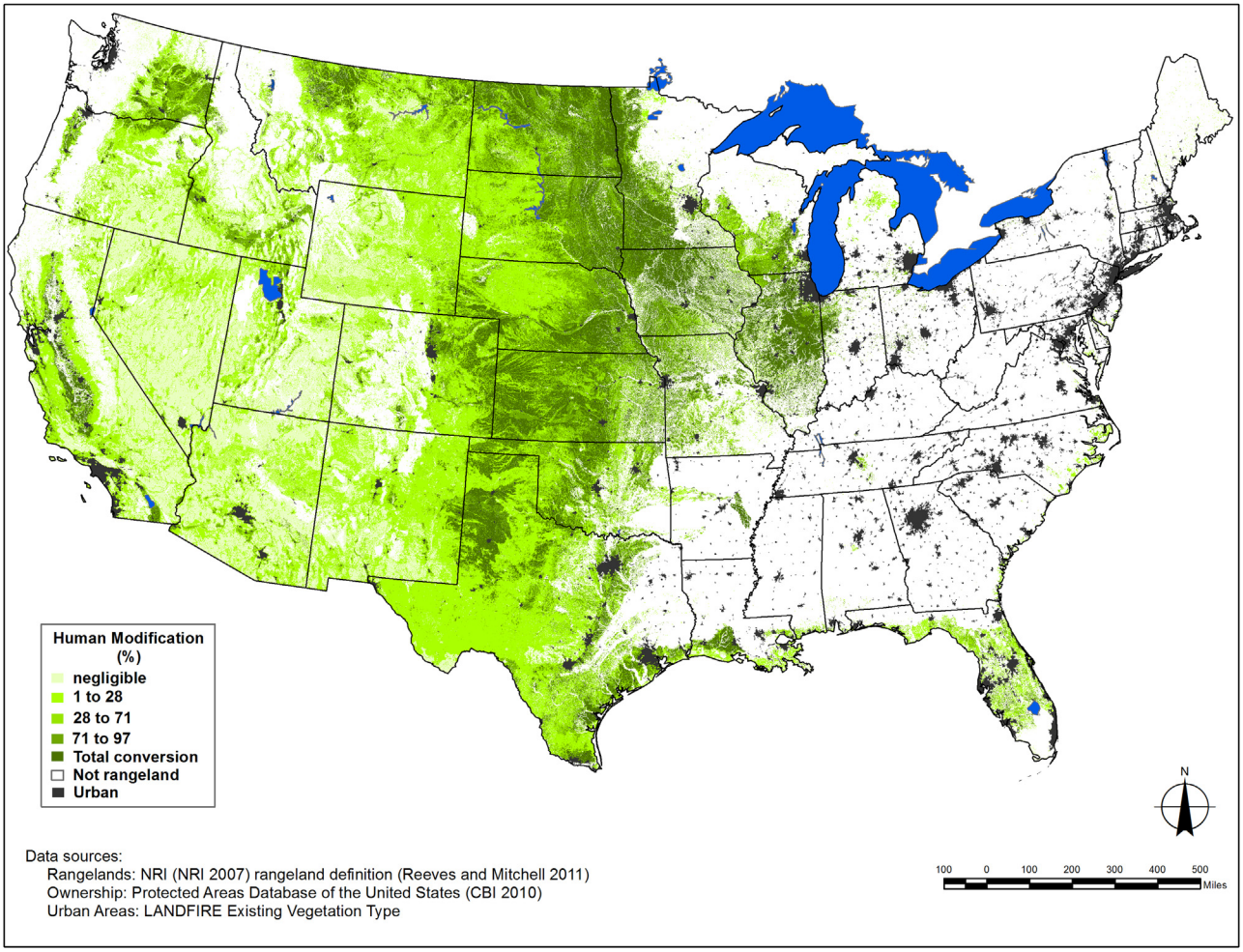


**Figure 2.** Extent and magnitude of human-modified land cover in the United States, displayed at a resolution of 90 m.[16] Roughly one-third of all rangelands circa 1500 is no longer rangelands, primarily due to conversion to crop agriculture, and many of the resulting crops (especially corn) are used to feed livestock in confined animal feeding operations.

so efficient because it tightly integrates ranching with farms, feedlots, and the processing industry. Events since World War II reinforced this overall pattern, even as the center of gravity of the industry shifted to the Southern Plains. Feedlots expanded to become confined animal feeding operations, and slaughterhouses decamped from Chicago and other cities for rural areas with cheaper nonunion labor and closer proximity to feedlots. As the scale and intensity of production have increased, however, a number of important changes have occurred. Beef production has increasingly abandoned the very thing enabling the success of the feedlot in the first place: the synergistic relationship between livestock and crop production, mediated by manure and soil fertility. Farms rely instead on synthetic fertilizers, and cattle and hogs are fed in confinement instead of in fields.[28] Additionally, corn production has grown well beyond what is needed for livestock feed. Large amounts are used to produce ethanol, sweeteners, and countless other products.

Today, the Corn Belt encompasses our most fertile land, has the highest rates of soil erosion and nutrient run-off, and receives higher levels of government farm payments than the rest of the country.[29] And it has become, arguably, too efficient. Productivity gains in US agriculture have exceeded those in industry and services, inverting the 19th century economic "miracle" for farmers and replacing it with a vicious cycle of rising output and declining profits. For all US farm households, rates of return are negative for small operations and modest for midsized operations.[28] Either you get bigger and bigger, or you turn to off-farm income to stay afloat. Or you subdivide: nationally, exurban development (1 home/0.4-16 hectares [1-40 acres]) increased from 5% to 25% of the lower 48 states from 1950 to 2000.[30]

Efficiency has been achieved largely by economies of scale. Nearly every segment of the US meat industry has become more consolidated since the 1980s—that is, the number of firms has declined and their average size has grown. The sales midpoint for feedlots (the size of the firm where half the national herd is on larger, and half on smaller, feedlots) has more than doubled since the 1980s, and consolidation in the processing sector has reached levels not seen since the early 20th century.[28] Interestingly, some economists say today's Big Four packers—JBS, Cargill, Tyson, and National Beef—do not ad-



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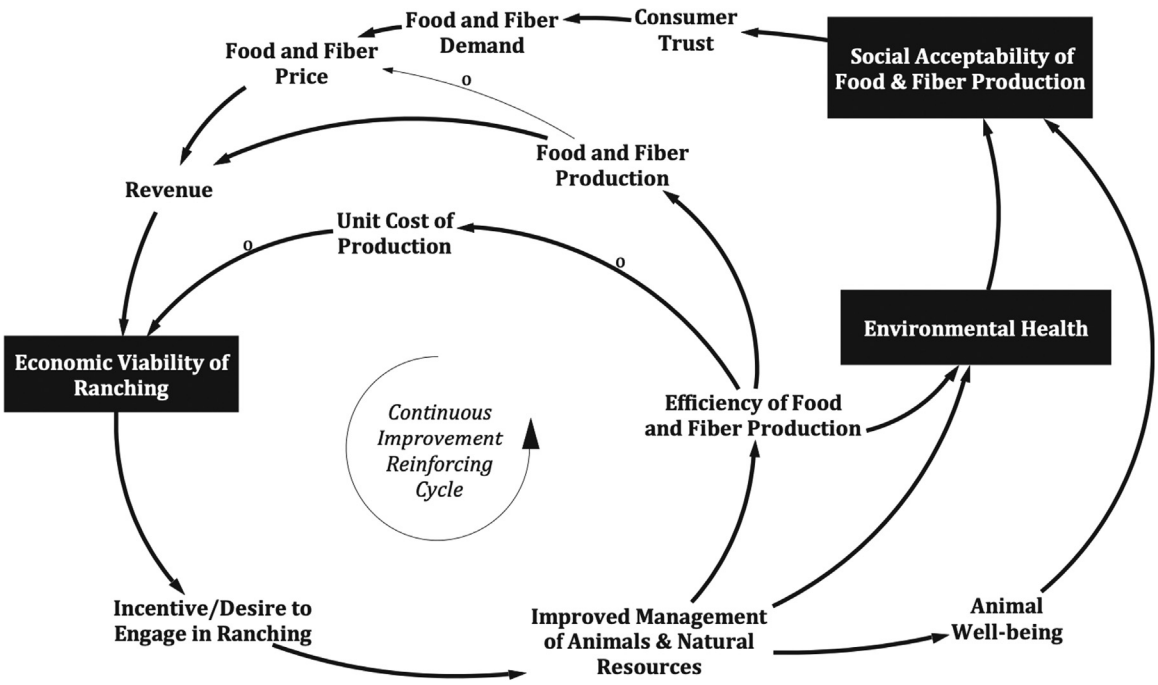


**Figure 3.** Interconnectedness of sustainability factors in sustainable ranching systems.[32] There are three negative relationships in the model (marked "o"). Two of the three cancel each other out: greater efficiency reduces unit costs, which increases economic viability. But the third does not, at least not in aggregate: greater efficiency increases output, which lowers price and reduces revenue.

versely affect prices for farmers, ranchers, or consumers because their plants are so efficient they save everyone money.[31] Nonetheless, their dominance compels everyone in the supply chain—ranchers, farmers, backgrounders, and feedlots—to conform to the production specifications of the major buyers. The largest packing plants are only more efficient than smaller ones, moreover, when they operate at extremely high rates of through-put, making meatpacking ever more dangerous for workers.

The sole exception to the consolidation trend is beef cow–calf operations,[28] probably because so many producers persist in the business for nonfinancial reasons. But they still must work within the context of the larger beef system. In a recent paper, Machen et al.[32] provide a useful model for understanding the sustainability of ranches today. As they note, greater efficiency enhances viability by reducing unit costs (Fig. 3). But it also increases aggregate output, which lowers prices and reduces revenue. It is the curse of overproduction, which has afflicted US agriculture since the end of World War I.[33] It expresses itself in declining purchasing power—more and more calves are needed to buy a new pickup truck, for example. Everyone except farmers and ranchers benefits from low food prices. Meanwhile, rising land values increases equity, but it decreases the rate of return-on-assets, expanding the gap between income from livestock production and potential income from other land uses. Land rich and cash poor, as the saying goes.

What lessons can we draw from this history to improve the prospects for sustaining rangelands in this century? First and most simply is to prevent—and wherever possible reverse—the loss of rangelands to other land uses. Livestock grazing may be damaging if poorly managed, but conversion to more intensive uses is nearly always more so. Second, recognize the diversity and variability of beef production in all its dimensions, including environmental impacts. This is especially important in considering GHG emissions, as intensive production on modern feedlots is in fact more efficient per unit of output than other systems. But there are downsides to this efficiency, and the third lesson is to reconnect the livestock–soil fertility–crop production cycle on which the original feedlot was based.[34] Reliance on synthetic fertilizers, rather than animal manure, is a bane not only for the environment but also for farmers. And finally, fourth, counteract the problem of over-production in agriculture. All of these goals would be advanced, incidentally, by a well-designed carbon tax.

Climate change complicates these lessons in important ways. This is urgently apparent with regard to wildfire; here we would benefit from better understanding of Native American management practices, especially in highly fire-prone settings such as California.[35] In many regions, higher temperatures are already reducing forage production and straining water supplies, making economic sustainability still more precarious, especially for small-to-medium scale ranch operations. This may lead to consolidation of ranches into larger units, or outright abandonment in some areas. And as society demands more renewable energy, rangelands face yet another competing land-use in large-scale solar and wind power installations (often called "farms," ironically enough). As important as these may be to mitigating climate change globally, they may nonetheless have negative ecological impacts on rangelands and rangeland users.[4]



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Sustaining rangelands in the 21st century will depend heavily on livestock and meat producers' social license to operate, or what Machen et al.[32] term the "Social Acceptability of Food & Fiber Production." Ranching currently is the strongest exhibit in support of social acceptability, both for its cultural values and for the expansive landscapes it helps to conserve. But its power to offset criticisms of the rest of the beef system is threatened by political and economic forces relegating rangelands to the margins of power. To succeed, rangeland advocates need to understand and engage with the entire beef production system, which paradoxically holds both promise and peril for the rangelands we have lost as well as for those we continue to enjoy today.

## Declaration of Competing Interest

The author declares the following financial interests/personal relationships which may be considered as potential competing interests. The author certifies that he has no financial interest in the subject matter discussed in the manuscript.

## References


1. Havstad KM, Peters DPC, Skaggs R, et al. Ecological services to and from rangelands of the United States. *Ecol Econ*. 2007; 64(2):261–268. doi:10.1016/j.ecolecon.2007.08.005.
2. Hobbs NT, Galvin KA, Stokes CJ, et al. Fragmentation of rangelands: implications for humans, animals, and landscapes. *Glob Environ Change*. 2008; 18:776–785. doi:10.1016/j.gloenvcha.2008.07.011.
3. Godde CM, Boone RB, Ash AJ, et al. Global rangeland production systems and livelihoods at threat under climate change and variability. *Environ Res Lett*. 2020; 15. doi:10.1088/1748-9326/ab7395.
4. Kreuter UP, Iwaasa AD, Theodori GL, et al. State of knowledge about energy development impacts on North American rangelands: an integrative approach. *J Environ Manage*. 2016; 180:1–9. doi:10.1016/j.jenvman.2016.05.007.
5. Gerber PJ, Mottet A, Opio CI, et al. Environmental impacts of beef production: review of challenges and perspectives for durability. *Meat Sci*. 2015; 109:2–12. doi:10.1016/j.meatsci.2015.05.013.
6. Eisen MB, Brown PO. Rapid global phaseout of animal agriculture has the potential to stabilize greenhouse gas levels for 30 years and offset 68 percent of CO2 emissions this century. *PLOS Climate*. 2022; 1(2). doi:10.1371/journal.pclm.0000010.
7. Spiegal S, Kleinman PJA, Endale DM, et al. Manuresheds: advancing nutrient recycling in US agriculture. *Agric Syst*. 2020; 182. doi:10.1016/j.agsy.2020.102813.
8. Spiegal S, Bestelmeyer BT, Archer DW, et al. Evaluating strategies for sustainable intensification of US agriculture through the Long-Term Agroecosystem Research network. *Environ Res Lett*. 2018; 13. doi:10.1088/1748-9326/aaa779.
9. Rivera-Ferre MG, López-i-Gelats F, Howden M, et al. Re-framing the climate change debate in the livestock sector: mitigation and adaptation options. *WIREs Climate Change*. 2016; 7:869–892. doi:10.1002/wcc.421.
10. Rotz CA, Asem-Hiablie S, Place S, Thoma G. Environmental footprints of beef cattle production in the United States. *Agric Syst*. 2019; 169:1–13. doi:10.1016/j.agsy.2018.11.005.
11. Herrero M, Havlik P, Vain H, et al. Biomass use, production, feed efficiencies, and greenhouse gas emissions from global livestock systems. *PNAS*. 2013; 52:20888–20893. www.pnas.org/cgi/doi/10.1073/pnas.1308149110.
12. Brice J. How Big Beef is Fueling the Amazon's Destruction. *Bloomberg*. 2022. Accessed 22 November, 2022. https://www.bloomberg.com/graphics/2022-beef-industry-fueling-amazon-rainforest-destruction-deforestation/ .
13. Harrison MT, Cullen BR, Mayberry DE, et al. Carbon myopia: the urgent need for integrated social, economic and environmental action in the livestock sector. *Glob Change Biol*. 2021; 00:1–36. doi:10.1111/gcb/15816.
14. Hudson JC. *Making the Corn Belt: A Geographical History of Middle-Western Agriculture*. Indiana University Press; 1994.
15. McCoy JG. *Historic Sketches of the Cattle Trade of the West and Southwest*. Ramsey: Millett & Hudson; 1874.
16. Dale EE. *The Range Cattle Industry: Ranching on the Great Plains from 1865 to 1925*. University of Oklahoma Press; 1930.
17. White R. *"It's Your Misfortune and None of My Own": A New History of the American West*. University of Oklahoma Press; 1991.
18. Sayre NF. *The Politics of Scale: A History of Rangeland Science*. University of Chicago Press; 2017.
19. Reeves MC, Krebs M, Leinwand I, et al. *Rangelands on the Edge: Quantifying the Modification, Fragmentation, and Future Residential Development of U.S. Rangelands*; 2018 USDA-Forest Service General Technical Report RMRS-GTR-382.
20. Noss RF. *Forgotten Grasslands of the South: Natural History and Conservation*. Island Press; 2013.
21. Anderson VD. *Creatures of Empire: How Domestic Animals Transformed Early America*. Oxford University Press; 2004.
22. Scott JM, Davis FW, McGhie RG, et al. Nature reserves: do they capture the full range of America's biodiversity? *Ecol Appl*. 2001; 11(4):999–1007. doi:10.1890/1051-0761.
23. Samson FB, Knopf FL, Ostlie WR. Status and Trends of the Nation's Biological Resources, *vol. 2*. Grasslands. US Geological Survey; 1998.
24. Zhang X, Lark TJ, Clark CM, et al. Grassland-to-cropland conversion increased soil, nutrient, and carbon losses in the US Midwest between 2008 and 2016. *Environ Res Lett*. 2021; 16. doi:10.1088/1748-9326/abecbe.
25. Booker J, Huntsinger L, Bartolome JW, et al. What can ecological science tell us about opportunities for carbon sequestration on arid rangelands in the United States? *Glob Environ Change*. 2013; 23:240–251. doi:10.1016/j.gloenvcha.2012.10.001.
26. Cusack DF, Kazanski CE, Hedgpeth A, et al. Reducing climate change impacts of beef production: a synthesis of life cycle assessments across management systems and global regions. *Glob Change Biol*. 2021; 27:1721–1736. doi:10.1111/gcb.15509.
27. Rui Y, Jackson RD, Cotrufo MF, et al. Persistent soil carbon enhanced in mollisols by well-managed grasslands but not annual grain or dairy forage cropping systems. *PNAS*. 2022; 119. doi:10.1073/pnas.2118931119.
28. MacDonald JM, Hoppe RA, Newton D. Three decades of consolidation in U.S. agriculture. *EIB-189*. US Department of Agriculture, Economic Research Service; March 2018.
29. David MB, Drinkwater LE, McIssac GF. Sources of nitrate yields in the Mississippi River basin. *J Environ Qual*. 2010; 39:1657–1667. doi:10.2134/jeq2010.0115.
30. Brown DG, Johnson KM, Loveland TR, Theobald DM. Rural land-use trends in the conterminous United States, 1950-2000. *Ecol Appl*. 2005; 15:1851–1863. doi:10.1890/03-5220.




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31. Wohlgenant MK. Competition in the US meatpacking industry. *Annu Rev Resour Economics*. 2013; 5:1–12. doi:10.1146/annurev-resource-091912-151807.
32. Machen RV, Sawyer JE, Bevers SJ, Mathis CP. Measuring economic sustainability at the ranch level. *Rangelands*. 2021; 43:240–245. doi:10.1016/j.rala.2021.10.005.
33. Cochrane WW. *The Curse of American agricultural abundance: A sustainable solution*. University of Nebraska Press; 2003.
34. Naylor R, Steinfeld H, Falcon W, et al. Losing the links between livestock and land. *Science*. 2005; 310:1621–1622. https://www.jstor.org/stable/3842952.
35. Lightfoot KG, Parrish O. *California Indians and their environment: An introduction*. University of California Press; 2009.

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