Sheep brains for breakfast

It's 7 am on a winter morning. I'm snuggled up in my flannel nightie alongside a tepid, koala-shaped, hot water bottle. This was before central heating. The smell of hot breakfast wafts in on the air, uniquely sweet, signalling Saturday morning. Fried sheep brains. A special treat reserved for the weekend, served as "brains for brekkie" to my father as he studied the horse racing form guide. My childhood weekends in the 1960s revolved around horses and sheep. The former of the racing and riding kind, and the latter as a frequent menu item. Lamb chops, fry (liver), tongue, leg, cutlets and Shepherd's pie. The crowning glory being the mouthwatering Sunday roast, lovingly prepared with three vegetables especially for my grandparents, dutifully collected from the North Balwyn tram terminus for their weekly visit. Over good-natured disputes as to who was most deserving of the coveted lamb shank that week, adults would sit around and reminisce about the olden days of depression era food rationing, toilet paper shortages, polio epidemics, Luna Park on a sixpence, anything except the war. That topic was off limits. As was the unspoken anguish of absent children and siblings. Those matters remained the purview of the stiff upper lip.

Alison Van Eenennaam

Cooperative Extension Specialist in Animal Genomics and Biotechnology, Department of Animal Science, The University of California, Davis

Australia, buoyed into prosperity by wool, was more sheep (159 million) than people (11 million) in the year I was born. There were more than 14 sheep for every person on the continent. Today, some 72 million sheep mean there are fewer than three per person in a land of 25 million people.

However, today's 72 million genetically superior sheep produced more meat (532 kilotonnes (kt) of lamb; 204 kt of mutton) in 2017–18 than did those 159 million sheep in 1963 (368 kt of lamb; 219 kt of mutton). In the 1960s, Australia commonly exported low-value frozen mutton to the United States (US) and the United Kingdom, but now exports 61% of its high-quality lamb, and 96% of its mutton, worth A$4.3 billion. Not to mention wool. During that same half century, Australian mutton and lamb consumption dropped from close to 50 kg/head annually in the sheep-centric meals of the sixties, to just over 8 kg of lamb and 0.3 kg of mutton per person in 2017–18.[1]

Simply put, Australians now consume around one-fifth of the amount of sheep meat they did in 1963. The sheep population has decreased by more than a half, and those remaining are more than twice as productive, thereby reducing the environmental footprint of a serving of lamb, while bringing in more than A$4.3 billion in export revenue in 2017–18. What an amazing all-around sustainability win for agricultural science and Australia!

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Yet, that is not how these developments play out in popular discourse. Red meat has become public enemy number one, despite the fact that lamb and beef consumption have decreased since the 1960s, while market share of less-expensive chicken has trebled, and pork has doubled. The Moreland City Council from my home state of Victoria recently banned meat from their council meals on Mondays.[2] Goldsmith's College in London has permanently removed beef from its menu.[3]

All around the world, urban think tanks are advocating plant-based diets, and Californian investors can't get enough of plant-based and cultured meat substitutes.[4] Such developments would seem to bode poorly for animal agriculture's future. But, with even a rudimentary understanding of Australia's environment and food systems, it is apparent animal agriculture is here to stay. Moreover, misinformation around this topic obfuscates the incredibly important role animals, particularly ruminants – hoofed animals that chew cud regurgitated from their rumen – play in meeting both human nutritional needs and the sustainability of global food systems.

Greenhouse gas emissions of animal agriculture

Avoiding meat is often couched as a way 'to save the planet', and wildly exaggerated numbers such as "animal agriculture is responsible for a staggering 51% of greenhouse gas (GHG) emissions worldwide"[5] are often used to support this premise. In actuality, the entire Australian agricultural sector was responsible for approximately 13% of Australia's GHG emissions, 71 Mt carbon dioxide equivalents (CO_2e), in 2017.[6] Livestock were responsible for about 11% of Australia's CO_2e: 10.4% for the ruminants (6.5% beef, 2.3% sheep, 1.6% dairy), and 0.4% pigs and other animals. For context, the majority, almost 70% of Australian GHG emissions (378 Mt CO_2e) in 2017, was from energy: electricity (33%), transportation (18%), and stationary energy generation (17%).

These numbers are similar to the values for other developed countries, where fossil-fuel based transportation and power generation are the two major sources of GHG emissions, and agriculture is around 10%. For example, in the US in 2017, transportation and electricity generation were responsible for more than half of the nation's GHG emissions, 29% and 28% respectively, whereas agriculture was 9%.[7] Of that, animal agriculture was responsible for

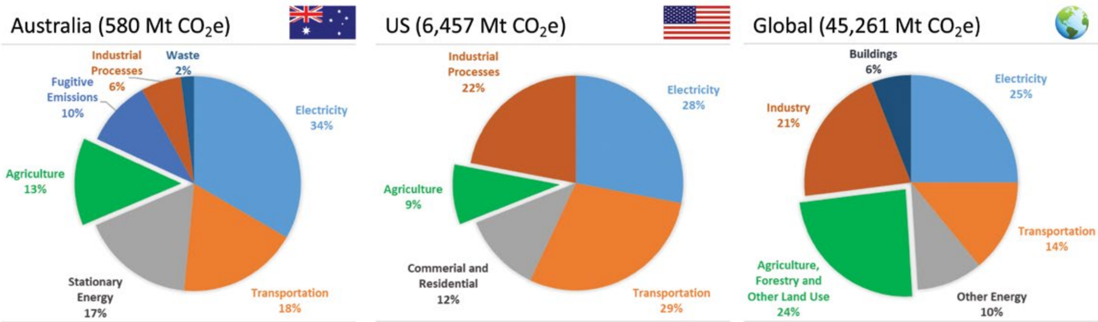

Figure 1: Breakdown of 2017 GHG by sector in Australia,[6] the US,[7] and globally.[8]

approximately 4% of total US GHG emissions (Figure 1).

One estimate reveals that eliminating ALL animal agriculture in America would decrease US GHG emissions by 2.2%, whilst resulting in numerous micronutrient deficiencies.[9] This comes nowhere near the potential GHG reductions possible by reducing fossil-fuel emissions. For example, a one-way flight to Europe produces more GHG than is saved annually by switching from an omnivore to a vegan diet.[10] Let alone the more substantive impact of even less palatable individual actions like having fewer children,[10] no car,[10] or no pets.[11]

These CO_2e numbers are based on weighting the global warming potential of ruminant-generated methane at 25–28 times the value of CO_2.[12] Although potent at trapping energy, methane is a short-lived climate pollutant; after 10 years it breaks down and enters the carbon cycle. Conversely, burning fossil fuels produces long-lived CO_2 that lingers in the atmosphere for 1,000 years.[13] The combined annual methane emissions of sheep and cattle in Australia has declined since the national cattle herd peaked in 1976 at 33.4 million head.[14] Because Australian ruminant numbers have been decreasing for well over 40 years, the methane attributed to today's livestock is more than offset by the cyclical breakdown of methane generated a decade ago. In other words, the atmospheric methane additions from Australia's ruminants are in approximate equilibrium with the breakdown of methane emissions from 10 years ago, meaning that their net atmospheric burden remains stable.

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Globally, animal agriculture is estimated to account for 14.5% of anthropogenic GHG emissions,[15] whereas fossil-fuel GHG emissions account for more than 80% of global CO_2e.[16] Livestock's contribution can be broken down into beef (5.9%), cow's milk (2.9%), pork (1.3%), buffalo milk and meat (1.2%), chicken meat and eggs (1.2%), and small ruminant milk and meat (0.9%). Like Australia, the global picture fingers the ruminants for around 10–11% of total emissions. A logical response might seem to be to call for the elimination of all ruminants – cows, buffalo, sheep, goats, yaks, antelopes, deer, giraffes, and their relatives. What would that world look like?

Who's eating what

Animal products such as milk, meat and eggs currently provide around 18% of the energy and 25% of the protein consumed globally; in developed countries, this rises to 20% and 48%, respectively. In terms of the global supply of animal protein, cattle and buffaloes make up the largest contribution, including meat and milk (45%), followed by chickens (31%, including meat and eggs), and pigs (20%). Small ruminants – sheep and goats – produce only about 4% of global animal-source protein.

However, they are a very important source of such protein in the developing world as they are able to upcycle plants that are inedible for humans into high quality protein. THAT is the magic super-power of grazing ruminants. The rumen's microbial population can transform inedible grasses and other cellulose-based forages into energy. The by-product of this transformation by methanogens is methane – belched via a process called eructation.

Pastoralists throughout the globe have traditionally herded large numbers of goats, camels, yak, reindeer, llama, and alpaca to utilise land that is otherwise too steep, dry, cold or hot for crop production. Many of these species can thrive and reproduce on exceptionally sparse vegetation and otherwise extreme environmental conditions. Although not currently part of global meat trades, these species are uniquely able to produce a source of high-quality protein and essential micronutrients in extreme environments and may play an important role in food security in the face of climate change.[17]

Rangelands occur in all biomes and comprise 18 to 80% of the world's land area, depending upon the definition used.[18] The vegetation of rangelands is generally comprised of grasses, forbs and/or shrubs with various levels of tree canopy cover. The most widespread human activity and dominant land use in rangeland ecosystems is livestock grazing.[19] Grazing ruminants are embedded in the definition of rangelands – "a natural ecosystem for the production of grazing livestock and wildlife."[20] Grasslands and their associated biodiversity frequently evolved with large hoofed herbivores; well-managed, herbivorous grazing by ruminants maintains rangeland health.[21]

Livestock consume an estimated 6 billion tonnes of feed annually, made up of 2.7 billion tonnes of grass and leaves, and 1.1 billion tonnes of crop residues. The production of global feed requires 2.5 billion ha of land, which is about half of the global agricultural area. Eighty percent of this area, 2 billion ha, is grassland of which about 1.3 billion ha cannot be converted to cropland. While livestock do consume one-third of global cereal production, 86% of what livestock consume globally is materials that are currently inedible for humans.[22] Removing livestock would mean that those materials would no longer contribute to the human food supply.

It is often reiterated that meat from monogastrics (e.g. chickens, pigs) should be substituted for ruminant (e.g. cows and sheep) products due to their superior feed:gain conversion rates. And while it is true that pigs and chickens have a better conversion ratio relative to ruminants,[23] an important question is, what are they converting? Monogastrics typically consume feed (e.g. cereals) that could otherwise have been eaten by humans, whereas grazing ruminants eat grass, leaves and other cellulose-based forages. In fact, when comparing human edible-protein as feed to protein product, ruminants are more efficient than monogastrics. On average, 2.8 kg of human-edible feed is required to produce 1 kg of boneless meat in ruminant systems; this increases to 3.2 kg for non-ruminants.[22] Put simply, pigs and chickens compete more directly, and less efficiently, for human edible food than do ruminants.

There is a lot of dryland in Australia that is not suitable for the production of food, or feed for monogastric (i.e. one stomach) animals. In 2017–18, 10 times more land (328 million ha) was used for grazing than was used for crop production (31 million ha).[24] Much of the land base in Northern Australia, grazed by tropically adapted cattle prized for their tolerance to heat and ticks, is not suitable for crops (Figure 2, over page).

Meat consumption has a long history in human evolution, likely going back to the earliest known human-like ancestor living 5–7 million years ago. Milk, meat and eggs are sources of high-quality protein, meaning they provide all of the 20 amino acids. In addition, animal source foods can provide a variety of essential micronutrients such as vitamin A, vitamin B-12, riboflavin, calcium, iron and zinc that are difficult to obtain in adequate quantities from plant source foods alone. Relatively small amounts of nutrient-dense animal source foods, added to a plant-based diet, can substantially increase nutrient adequacy.[25] Therefore, from a nutritional perspective, maybe grandma was right with the old dictum "everything in moderation". It may

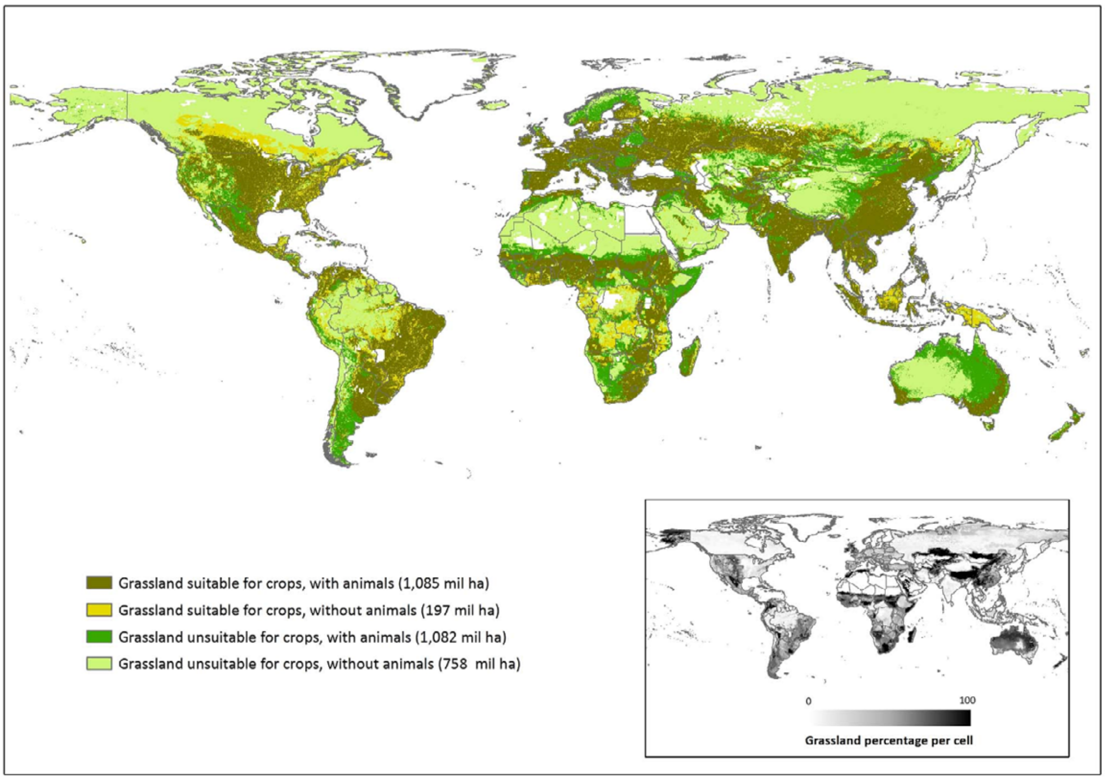

Figure 2: Global grasslands suitable and unsuitable for crop production and share in land-use.[22]

be that the middle ground of individual dietary action is to eat plant and animal-based foods in moderation, rather than the more extreme position of eliminating all animal products.

More than hamburgers

Some view the consumption of animal products through the focused lens of the environmental and health crises of the urban Western world.[26] This perspective ignores the ongoing problem of hunger and micronutrient deficiencies that still affect millions of poor people worldwide, especially in rural communities. The discussion often fails to acknowledge the nutritional importance of high quality animal protein in the diets of the rural poor, and the numerous non-nutritional benefits of livestock production in developing countries. Livestock contribute 40% of global value of agricultural output, support livelihoods and food security of 1.3 billion people,[27] provide food and incomes, consume non-human edible food, and provide essential micronutrients (e.g. iron, calcium) that are more readily available in meat, milk, and eggs than in plant-based foods. They also provide fibre, hides, a variety of by-products, building materials, traction, and transportation. Livestock are the only source of property for the underprivileged in some cultures and may serve as a store of wealth, collateral for credit, and an essential safety net during times of crisis. They are central to mixed farming systems, help control insects and weeds, and importantly produce manure for fertiliser, and waste for cooking. Additionally, they provide employment, in

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some cases especially for women, and have widespread cultural significance as the basis for religious ceremonies. A case in point is India, a predominantly vegetarian country and home to 46.6 million stunted children,[28] a third of the world's total, while simultaneously worshipping and home to 300 million cows, the largest cattle population of any country on Earth.

Patrick Brown, former biochemistry professor and now founder and CEO of Impossible Foods, a company producing plant-based meat substitutes, has a mission of "completely replacing animals in the food system by 2035".[29] I wonder if he has considered the sacred cows in India, or the village chickens in Africa, or the goats, camels, yak, reindeer, llama, and alpaca of indigenous pastoralists. Replacing all animal source food in the next 15 years is an audacious goal, even by Silicon Valley standards. By 2035, the FAO estimates that 1,680,736 kt of animal products will be produced globally in that one year. Just for context, that is around the weight of *fourteen quadrillion, eight hundred seventy three trillion, seven hundred seventy three billion, nine hundred thirty two million, nine hundred twenty thousand, four hundred* Impossible Burgers!

However, more profoundly, humankind's association with domesticated animals is not merely 'a technology' to make hamburgers. Rather, it is a critical bond to the wellbeing of millions, possibly billions, of people in many developing countries.

Brown's pronouncement is based on his stated belief that "producing meat from animals is a prehistoric technology which is incredibly inefficient and which has not fundamentally improved in millennia." While these types of bold statements and hubris might be attractive to venture capitalists, they are belied by the tremendous improvements that have been achieved in the efficiency of livestock production because of improved genetics, better diets, and more sustainable land management practices. However, more profoundly, humankind's association with domesticated animals is not merely 'a technology' to make hamburgers. Rather, it is a critical bond to the wellbeing of millions, possibly billions, of people in many developing countries. There, a small amount of animal protein intake, such as an egg a day, during the first five years of life can improve childhood nutrition and help prevent stunting.[30] Brown's unnecessarily confrontational and implausible claims seem counterproductive. There will be a need to increase protein from all sources given projected human population growth. A more fruitful approach would seem to be promoting research on how to produce BOTH plant and animal source proteins more efficiently.

Efficiency is key

Efficiency of agricultural systems is inversely proportional to the environmental footprint per unit of production.[31] It is hard to overstate the impact of improved genetics, nutrition, and veterinary care on decreasing the GHG associated with animal source food production. For example, today in the US there are only 9 million dairy cows, 17 million fewer than existed in 1944, efficiently producing 1.6 times more milk than did those 26 million cows in the 1940s.[32]

If GHG footprint were the only consideration, Figure 3 (over page) could simplistically lead to the conclusion that all regions should adopt North American-style intensive production systems, or that dairying should be focused in productive areas and discouraged in less-productive regions such as sub-Saharan Africa and South Asia. However, less intensive pasture-based dairying makes sense in Australia and New Zealand, and the significant nutritional and economic value of dairying in less-developed regions must not be underestimated. India is the world's largest milk producer, contributing 21% of global production with the largest cattle population, 300 million, approximately 30% of the global herd.

The challenge for global animal agriculture is to improve productivity and optimise sustainability within each region rather than prescribe one-size-fits-all production systems or management practices. With the goal of continuous improvement, Australian livestock producers routinely apply the latest science

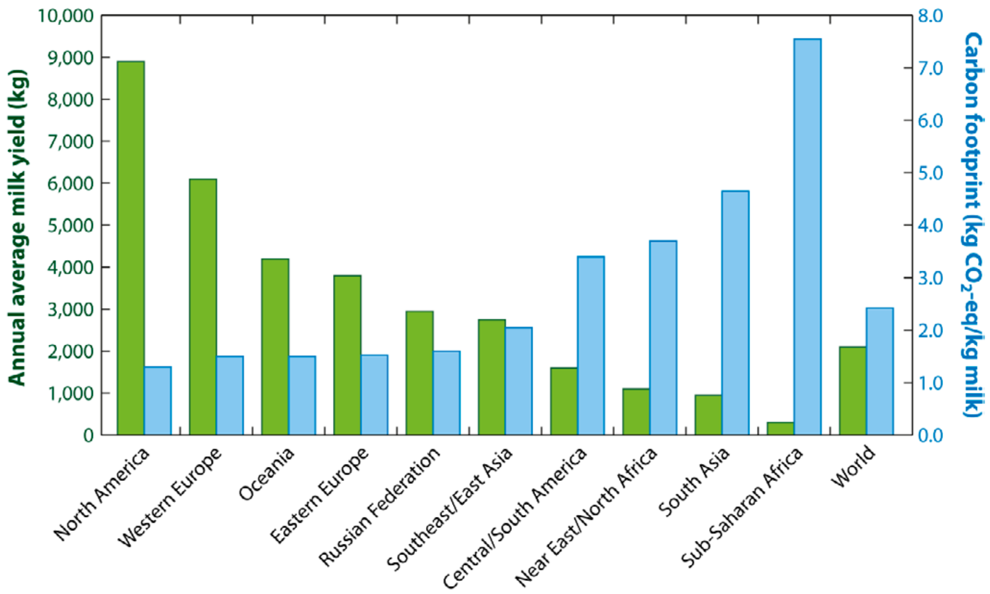

Figure 3: Average annual milk yield and carbon footprint per kg milk across global regions. Milk yield per cow is inversely proportional to carbon footprint/kg milk. Data from FAO.[31]

and technology to improve performance, thereby decreasing the emissions intensity of animal source foods,[33&34] and they will continue to do so given social licence. Future global food demands will require significant gains in production efficiencies, and likely contributions from alternative protein sources as well. These two things are not mutually exclusive.

Path to carbon neutrality

There is also a sustainability story to be told in terms of the red meat industry in Australia. Between 2005–15 GHG emissions from the Australian red meat industry almost halved, decreasing from 124.1 to 68.6 Mt CO_2e in 2015, primarily through reductions in land clearing and animal numbers.[35] In 2017, the Australian red meat industry took on the ambitious goal to be carbon neutral by 2030. This will likely require a range of strategies to sequester carbon and improve production efficiencies. It will also require policy support from private and government bodies to promote the development of drought-resilient forage varieties, carbon farming, and grassland stewardship in the face of climate variability for the triple benefit of production, reducing emissions, and ecosystem health.[35]

Most people would agree that having a reduced or zero emission Australian red meat sector would be a good thing. That is a shared value of many consumers. Likewise, healthy functioning ecosystems (soil, water, plants, and animals) would seem to be a societal good. Yet, the paths to achieve these mutually agreeable outcomes necessarily involve the use of technology and trade-offs that some will find at odds with their perceptions and ideals. For example, one way to decrease the emissions intensity of beef is to finish cattle in feedlots. Feedlot finishing reduces GHG emissions by decreasing the number of grass-fed cattle, reducing age at slaughter, and increasing the weight at slaughter. The trade-off is that human edible food is used to finish ruminants, disassociating them from their magic super power of digesting cellulose. Additionally some view such confinement as a negative for animal welfare. Another useful technology to decrease days to finish, and therefore GHG, is the use of hormonal growth promotants (HGP). But some retailers made a calculated decision to attempt to increase market share by prohibiting this technology from their supply chain due to negative consumer perception, a potential short-term market gain for an unspoken long-term negative environmental impact.

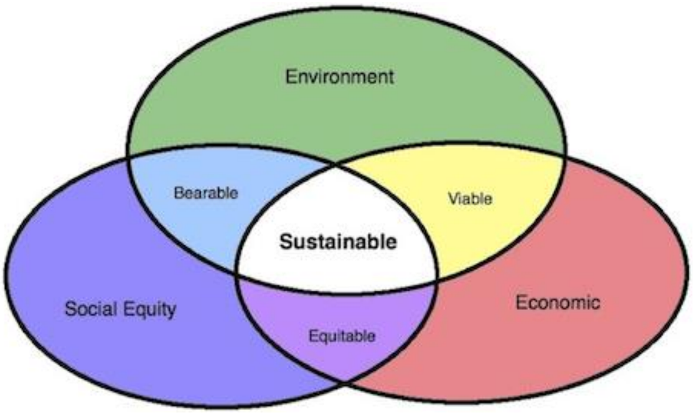

Figure 4: The interconnectedness of the three pillars of 'sustainable' food production systems.

Sustainability of food production

What will be the future of Australia's solar-driven converters of inedible cellulose on non-arable land? Given most people have a shared interest in 'sustainable' food production systems, I like to ponder the three pillars of sustainability – environment, economic, and social equity – when contemplating changes to agricultural production systems (Figure 4). Different people and groups will weight these according to the metrics or values they hold most dear. There is no wrong weighting, but there are very real evidence-based trade-offs associated with different choices.

Although it may seem like switching to a diet with less red meat and more fruits, nuts and vegetables should be desirable from an environmental perspective, these substitutions are associated with relatively high energy and water use per calorie of these alternative food products.[36] It gets even more complicated when considering a nutritionally-balanced diet. Added sugars, fats, oils, and grains require fewer resources and create fewer emissions per calorie. Although these might be the most environmentally friendly sources of calories, they are not likely to be the ones recommended for consumption in large quantities as part of a healthy diet.

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The bottom line is that food is more than calories and nutrients. It is personal, cultural, and the centerpiece of Sunday roasts. The choices people make are a mix of taste, income, background, convenience, tradition, and availability. Adding in sustainability metrics brings in multiple competing goals, and often-conflicting outcomes emerge depending upon which metric or pillar of sustainability is being given credence. The most environmentally friendly diet might be the least healthy option, or the least palatable, or the most expensive, or culturally unacceptable. Eating Phar Lap, Red Dog or Moggie is probably a non-starter in Australia, although it would clearly help offset the considerable equine, canine and feline GHG emissions with some edible product. Pet rocks anyone?

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All or none

What concerns me about the future of animal agriculture in Australia is the current dichotomous framing of discourse around controversial scientific topics, especially in agriculture. Certain groups are so wedded to their viewpoint, that they are willing to ignore trade-offs and use any means necessary to influence the public debate and policy in support of their worldview. Some consider the absolute avoidance of all animal source products as their singular goal. Whether this is from the perspective of animal rights, or the environment, or some other value, there is an almost religious fervour to convert the 'unwoke' to this viewpoint. This has recently even included invading Australian farm homesteads.[37] No serious consideration is given to the potential impacts of such an outcome on farm families, grazing ecosystems, replacement of the food currently produced on non-arable land, or the impact on the world's food insecure people. Impartial expert opinion that attempts to outline the likely outcomes associated with such dramatic food system changes is routinely ignored, or discredited as 'big' [insert applicable industry] 'propaganda'.

Being ignorant of sustainability trade-offs resulting from advocated changes does not absolve accountability from those who pushed for those changes, especially if they swayed public opinion by misleading or flat-out inaccurate information.

Agricultural professionals need a seat at the table when dramatic changes are being proposed to global food systems. But they are having a hard time making themselves heard on such an emotional topic as animal agriculture in the era of social media. A shocking image of inhumane slaughter practices, easily eclipses the impact that Dr Temple Grandin's more representative 'Video Tour of a Lamb Plant'[38] might have on public opinion, although at 6.6 million views she is reaching more than most.

Bombastic, anthropomorphised statements such as "factory-farmed female animals endure being raped repeatedly"[39] to describe artificial insemination (AI), are invoked specifically to incite public outrage. Apart from the obvious affront to rape victims, what is missing is the rest of the story, and how this technology impacts commonly-shared values. For example, AI is used in the dairy industry to take advantage of the best genetics, to benefit animal health, and to support the safety of people who work on farms. It has also helped reduce the carbon emissions associated with a glass of milk by two-thirds since 1944.[32] That beneficial impact might be of little concern to someone who does not drink milk, but the negative environmental impacts of blocking farmer access to valuable technologies occur nonetheless. Being ignorant of sustainability trade-offs resulting from advocated changes does not absolve accountability from those who pushed for those changes, especially if they swayed public opinion by misleading or flat-out inaccurate information.

We could eliminate all food-producing animals from Earth. That viewpoint is often the purview of fortunate, well-nourished individuals with ample alternative dietary choices to meet their nutritional needs. However, in doing so we would need to replace 18% of the energy and 25% of the protein consumed globally, and do so without the millions of hectares in Australia, and 1.3 billion hectares globally of grasslands that are unsuitable for crops, or the 5.16 billion tonnes of livestock feed that is human-inedible (e.g. leaves, grass, silage and crop residues). Moreover, the livelihoods and food security of the 1.3 billion people currently dependent on livestock would need to be assured. For them, access to animal products may well be the difference between life and death.

I posit that at the current time there is no known, viable substitute for animal agriculture. 'Move fast and break things' might be a fitting adage in systems where no great harm results from upheaval. Making major changes in agricultural ecosystems should be undertaken with great care and a thorough understanding of the system-wide implications of such changes on the interconnected pillars of sustainability, especially when contemplating reforms to 40% of the global agricultural output of the world's food systems.

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About the author

Alison Van Eenennaam is a Cooperative Extension Specialist in the field of Animal Genomics and Biotechnology in the Department of Animal Science at the University of California, Davis. She received a Bachelor of Agricultural Science from the University of Melbourne, and both an MS and a PhD in Genetics from UC Davis. A passionate advocate of science, Dr Van Eenennaam has given over 650 invited presentations to audiences globally, and was the recipient of the Council for Agricultural Science and Technology (CAST) 2014 Borlaug Communication Award, and the American Society of Animal Science 2019 Rockefeller Prentice Award in Animal Breeding and Genetics.