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SUMMARY

Grazed and confused?

Ruminating on cattle, grazing systems, methane, nitrous oxide, the soil carbon sequestration question – and what it all means for greenhouse gas emissions

Tara Garnett,* Cécile Godde,* Adrian Muller, Elin Röös, Pete Smith, Imke de Boer, Erasmus zu Ermgassen, Mario Herrero, Corina van Middelaar, Christian Schader, Hannah van Zanten

* Lead authors

Food Climate Research Network
Oxford Martin Programme on the Future of Food
Environmental Change Institute, University of Oxford

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Ruminants – cattle, buffalo, sheep and goats – get a bad press in the environmental literature, the popular media and, increasingly, the public imagination. They emit large quantities of methane, use vast tracts of land, and are held responsible for a host of environmental ills, most notably climate change, deforestation and biodiversity loss, and the pollution of soils, air and water. Most studies conclude that ruminant products are among the most emissions and resource intensive of all the foods we consume. Within ruminant production systems, extensively reared grazing systems – where animals predominantly feed on grass – are the worst because they are less productive, if measured in terms of meat or milk output per unit of greenhouse gases (GHG) emitted.

Beef, it is argued – and especially grass-fed beef – is *bad*.

But an increasingly vocal opposition to this view can be heard from stakeholders who argue that although ruminants emit GHGs, the lands they graze on also contain large stores of carbon, and crucially, that the animals' grazing actions actually stimulate the sequestration of carbon in soils. What is more, the nitrogen in their manure can substitute for energy intensive synthetic fertiliser inputs, also leading to avoided emissions. As to the methane these animals emit, a distinction should be made between the climatic effects of this potent but short-lived gas and the permanent impacts of fossil fuel-generated carbon dioxide. In any case wild herbivores also produce methane; farmed ruminants simply substitute for the vast numbers that used to roam the planet and that we have hunted to extinction. In fact a move *away* from grass-based ruminant production could – the argument continues – actually make climatic matters worse rather than better, since a global shift towards diets rich in commodity oils, grains, sugars and the pig and poultry products whose production depends on arable crops will cause pastures to be ploughed up, leading to soil carbon and biodiversity losses.

In other words, grass-fed beef – the argument runs – is not just *good*, but *essential to* a low emitting sustainable food system.

These are the extremes of opinion and serve to delineate the parameters of the debate; there is in fact a great deal of confusion as to the merits or otherwise of grass-fed beef. The rationale for undertaking this study has been to try to provide some clarity in what is a complex debate. **It addresses just one specific concern: the role of ruminants in grazing systems in the net GHG balance.** There are of course many other important social, ethical and environmental issues that need exploring if one is to arrive at an informed and rounded conclusion about the merits or otherwise of grass-fed livestock and grazing systems for overall sustainability; but since the GHG question is difficult enough as it is, we confine our analysis only to this.

In our study we asked three questions, exploring the arguments and counterarguments. **First**, can ruminants in grazing systems help soils sequester carbon and if so how far does this benefit counteract their emissions? **Second**, how important are methane and nitrous oxide, also consequences of ruminant production? **Third**, what role have grazing systems historically played in driving damaging land use change and associated CO_2 release and how is this role changing?

Table 1: The bones of the dispute.

	Area of contention	Argument	Counterargument
1 (see Chapters 2 & 3)	The balance between greenhouse gas (GHG) emissions and removals.	Ruminants are a major source of GHG emissions, particularly carbon dioxide (CO_2) via land use change, methane (CH_4) and nitrous oxide (N_2O); any soil carbon sequestration arising is small, uncertain, time-limited, reversible and difficult to verify.	Ruminants in well-managed grazing systems can sequester carbon in grasslands, such that this sequestration partially or entirely compensates for the CO_2, CH_4 and N_2O these systems generate.
2 (see Chapter 4)	The importance of methane as a contributor to the climate problem. The role of the nitrogen cycle.	CH_4 is a particularly potent GHG and ruminants are significant contributors Livestock are a source of N_2O, a highly potent GHG. More broadly, efforts to sequester carbon risk incurring increases in nitrous oxide emissions. Livestock do not add any new nutrients to the land, but rather introduce an additional very leaky cycle.	CH_4 has a short life span; CO_2 from burning fossil fuels is a greater concern for permanent warming and shifts the balance of culpability onto CH_4 'efficient' but fossil-fuel dependent intensive systems. Historically wild ruminants roamed on many grasslands, producing CH_4. Farmed ruminant emissions need to be seen in the context of this historical baseline count. Livestock play a vital role in recycling nutrients – including nitrogen – and make them more available for plants to take up, thus fostering a new generation of plant growth.
3 (see Chapter 5)	Grazing systems and their role in land use (LU) and land use change (LUC) as compared with intensive monoculture crops and monogastric systems; the historical role of ruminants on the land.	Ruminants in grazing systems occupy a large land area and have historically caused LUC and associated above/below ground carbon release. Plant-based diets and grainfed intensive livestock systems use less land and so cause less damaging land use change.	Many grasslands are the natural climax vegetation and not suited to cropping. Crop production – for human food and intensive animal feed – increasingly drives land use change, and encroaches onto carbon-storing pastures.

This report is based on an extensive and detailed – although necessarily non-exhaustive – review of the peer and non-peer reviewed literature. Led by the Food Climate Research Network, it reflects two years of close collaboration between researchers at the Universities of Oxford, Aberdeen and Cambridge in the UK; Wageningen University in the Netherlands; the Centre for Organic Food and Farming (EPOK) at the Swedish University of Agricultural Sciences (SLU); the Research Institute of Organic Agriculture (FiBL) Switzerland; and the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia, who collectively have expertise in animal sciences, soil science, life cycle assessment, organic production systems, ecology and biodiversity conservation.

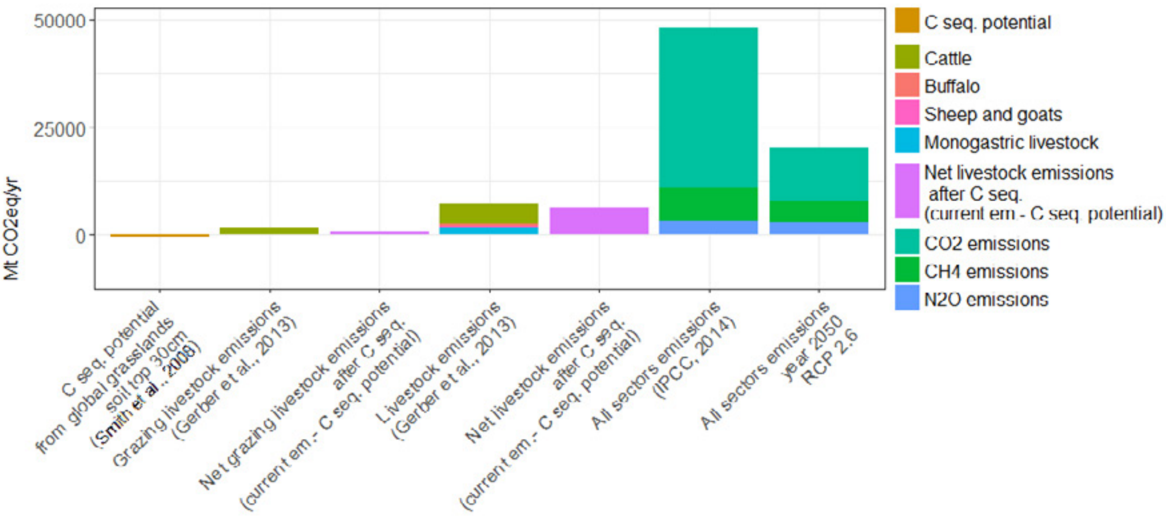
Our main findings are:

1. The contribution of grazing ruminants to soil carbon sequestration is small, time-limited, reversible and substantially outweighed by the greenhouse gas emissions they generate.

The evidence suggests that managed grazing in some contexts can cause carbon to be sequestered in the soil – and at least can provide an economic rationale for keeping the carbon in the ground. But at an aggregate level, the overall potential – depending on the level of ambition – would offset 20–60% of emissions from grazing systems; 4–11% of total livestock emissions; and between 0.6 and 1.6% of total annual anthropogenic greenhouse gas emissions – to which of course livestock also substantially contribute (Figure 1).

What is more, since soils reach carbon equilibrium – carbon flows in match carbon flows out – after a few decades, any sequestration that good grazing, or any other land management practice can achieve will be time limited. No more carbon will be accumulated. A shift in management practice can also cause gains to be reversed as can natural factors such as drought. Poor grazing management – which is prevalent – causes soil carbon to be released.

Figure 1: Grazing ruminants, their emissions, their sequestration potential and the 2°C warming limit.



Note: The final column (RCP2.6) shows the maximum allowable annual emissions from all sources that are consistent with the target to limit the global rise in temperatures to no more than 2°C above pre-industrial levels, as set out in the Paris Climate Accord.

It is also worth noting that, while very important to food security for some communities, solely grassfed animals currently contribute very little to total human protein intakes – at about 1 g/person/day – as compared with 31 g/person/day from all animal sources and 49 g/person/day from plant sources. The contribution is as low as it is because most grassland is used in mixed crop-livestock and to a lesser extent in other livestock systems too. The potential contribution, if all grassland was used for solely grassfed animals, to human protein availability would therefore of course be higher than this 1g and is discussed further below. Nevertheless grasslands simply cannot supply the global human population with the quantities of animal protein we currently eat, still less what we are anticipated to consume, without incurring significant expansion in overall grazing ruminant numbers – which would trigger catastrophic land use change and higher net greenhouse gases.

While proponents of holistic, rotational or adaptive grazing management have made large claims about the potential for carbon sequestration in grazing land, these rest on extrapolation from a small number of case-studies. Peer-reviewed studies of these systems give mixed results, and where benefits are shown, the numbers are small.

Leaving aside any scope for sequestering carbon it is imperative that we 'keep carbon in the ground.' Released carbon causes permanent warming. Avoiding carbon *release* by acting to halt degradation or conversion to croplands is even more important than trying to sequester it from the atmosphere.

2. Efforts to sequester carbon, and to reduce methane, carbon dioxide and nitrous oxide emissions may not always align. There will be trade-offs, often highly context specific. The overall impact of grazing systems on climate change depends on the *net balance* of all emissions and all removals.

Methane really is a problem. We examined the argument that, because methane's impacts are transitory, they are not important. This argument is false. Although the warming effect of any given pulse of methane is temporary, the total warming impacts will continue for *as long as the source of methane continues.* If ruminants continue to be reared, methane will continue to be emitted, and will continue to exert a warming effect. The problem of livestock-related methane only goes away if ruminant production is halted. Methane emissions also increase our risk of 'overshooting' the target to limit the rise in temperatures to less than 1.5°C/2°C, potentially tipping us into unknown climatic territory, with possibly devastating effects on agriculture, wildlife's ability to adapt, heat stress in humans and animals, and more. While prehistoric methane emissions from wild ruminants may have been similar to emissions today, the context 11,000 years ago – a tiny human population, with no use of fossil fuels – was so different that it is impossible and meaningless to make comparisons with the situation now.

As for nitrous oxide, the nitrogen and carbon cycles interact in complex ways and influence the net GHG balance in grazing systems. Nitrogen is essential to plant growth; and plants need to grow if carbon is to be sequestered in soils. But, whatever its source (mineral, organic or legume based), adding nitrogen to soils to promote growth and so foster soil carbon sequestration can cause increases in N_2O emissions such that these undermine or outweigh any sequestration gains.

All livestock, including ruminants, cause nitrous oxide emissions via their excreta, although the amount varies by animal type, production system and approach to manure management. Of course animal manure, as a source of nitrogen, also has the virtue of delivering nitrogen to plants in a readily available form: much is often made of ruminants' role in fertilising soils in this way. However, livestock – including grazing ruminants – are not a source of *new* nitrogen via their manure. They simply redeposit the nitrogen previously already embodied in the plant matter grown locally, or imported from elsewhere in animal feed.

And the nitrogen cycle is leaky. Nitrogen is exported in the form of milk, meat and animal carcass, and there will also be losses to the air and waterways. Lost nitrogen needs replacing through use of fertilisers or legumes; or the animal stocking rates need to be low enough to enable the natural process of nitrogen replenishment (via naturally present legumes and bacteria) to proceed. Ruminant manure is not – as it were – a free lunch.

3. Rising animal production and consumption – of all kinds and in all systems – risks driving damaging changes in land use and associated GHG release.

Grazing ruminants have historically been one of the major drivers of deforestation and its attendant ills; a quarter of the earth's land surface now consists of rangelands and pasture, much of which was previously forest. Today, while forest clearance for pasture continues in some regions, the nature of land use change and its causes are also shifting.

Even as the threat from the grazing ruminant sector remains, growth in pig and poultry production and intensive confined systems represent new causes of land conversion. Forests are still being cleared but grasslands, with their enormous carbon stores, are increasingly at risk. Demand for soy and grains to feed monogastric pigs and poultry and to support intensive ruminant production is driving grassland conversion and the release of its stored carbon into the atmosphere. But the grazing sector itself is another source of threat, as grasslands are intensified to support higher livestock numbers per unit area. This process of intensification may not cause a loss of soil carbon but the use of fertilisers generates N_2O emissions, on top of the methane that the animals emit, and biodiversity is diminished.

As to the future for land use, this is inherently uncertain. What happens will depend on trends in crop and livestock productivity; trajectories of food demand, the existence or otherwise of effective regulations limiting land use change; as well as larger global forces, from war and migration through to social movements; as well as technological 'wild cards'.

Scenarios exploring future land use suggest a very wide range of possibilities. One risk is that grasslands will be lost unless yield improvements manage to keep up with the increase in food and feed-crop demand. Productivity gains may reduce land pressures because less land is needed per unit of output; but they may also increase them via the rebound effect – greater productivity can lead to greater profits or reduced costs to consumers, so increasing incentives for both production and consumption. These, in the absence of effective policies, can stimulate further agricultural expansion or land alteration.

Growth in monogastric and in intensive production systems are certainly problematic: the prospect of an industrialised white meat future could not only drive further grassland conversions and exacerbate pressures on existing arable land, but would also raise other very serious societal, environmental and ethical concerns. But the alternative – growth in the grazing ruminant sector – is no solution either. If grazing ruminant systems were to supply all our projected meat demand we would have to massively expand grazing land into forest and intensify existing grasslands through the use of nutrient inputs, which among other things, would cause devastating CO_2 release and increases in methane and nitrous oxide emissions.

A possible third way would be a 'livestock on leftovers approach': this would limit production *and associated consumption* to what is possible from rearing animals on grasslands and feeding them waste streams, crop residues and agricultural by-products. Arable crops would not be fed to animals and further land use change would be avoided. If we obtained our animal protein from grasslands alone – that is, just from ruminants in grazing systems – per capita daily supply of animal protein could be increased to between 7–18g depending upon, among other things, assumptions about animal productivity. The additional use of food waste, crop residues and crop by-products as feed for pigs and poultry could increase the supply to 21g. The global forecast daily per capita average animal protein supply in 2050 (from all livestock types) is 31g. This approach therefore implies a moderation in anticipated animal protein intakes, especially in high income regions where the average is already 50-60g.

It is important to emphasise that even this 'livestock on leftovers' approach cannot be characterised as environmentally benign. Direct GHGs would persist – and grasslands are not an environmentally cost-free resource. There are almost always alternative uses. Land used to graze animals could potentially be used for nature conservation, for forests, for bioenergy, or a fraction of it for less land-demanding crop production. Moderating animal product consumption could free land for these other uses and would also increase the option space for adopting less intensive crop and animal production systems. We have choices.

What, then, are our overall conclusions?

Animal farming has brought humanity huge benefits – it produces food that is nutrient dense, much liked and culturally significant. Farm animals can convert biomass that humans cannot eat into food that we can. They provide income, livelihoods and in some parts of the world livestock keeping constitutes a survival strategy. But to raise the animals we eat and use, we have cleared forests, driven species to extinction, polluted air and waterways, and released vast quantities of GHGs into the atmosphere. The rearing of animals has transformed the face of this earth.

While in days and places where population densities were or still are sufficiently low and land abundant, livestock played, and continue to play, an important role in transferring nutrients from grasslands and onto croplands via their manure. But their traditional role in nutrient cycling is diminishing and no longer possible *if we continue to demand ever more meat*. That reality has triggered the development of new production systems that may be more efficient in certain respects but that also generate a whole new set of environmental and other problems.

The challenge for now and the coming years is to figure out the environmentally least-bad way of using land and other resources to nourish ourselves and meet our other developmental goals. The prevailing assumption that animal production must grow to meet demands for high animal protein diets in affluent and increasingly in emerging economies needs questioning.

While grazing livestock have their place in a sustainable food system, that place is limited. Whichever way one looks at it, and whatever the system in question, the anticipated rise in production and consumption of animal products is cause for concern. With their growth, it becomes harder by the day to tackle our climatic and other environmental challenges.

Citation
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