

We Measure Methane: What Does the Cow Give Back?

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Abstract

Cattle are frequently evaluated for their climate impact primarily through enteric methane emissions, but these represent only one component of a livestock production system. Grazing cattle also recycle nutrients through manure and urine, potentially reducing requirements for manufactured fertilizer, while pasture management can influence soil carbon accumulation or loss. Research from the Azores demonstrates substantial nitrogen return from grazing animals, while long-term grazing research shows that measured changes in soil carbon can materially alter the calculated carbon footprint of beef production. These benefits do not eliminate methane emissions, nor do they make grazing cattle inherently climate-neutral. They demonstrate the need to evaluate emissions, nutrient cycling, fertilizer substitution, soil carbon, and food production within the same system. A more complete assessment of cattle's climate impact therefore requires accounting for the entire grass–animal–soil cycle rather than methane emissions alone.

The fertilizer hidden in the pasture.

When we talk about cattle and climate change, we often reduce the animal to one number: methane. A cow eats grass, produces methane, and that methane is converted into kilograms of carbon dioxide equivalent. The number is real, but it is not the whole story.

A grazing cow is part of a biological system. It consumes plants, converts vegetation that humans cannot digest into food, returns nutrients to the land, and participates in the continuous cycle among grass, soil, animals, and the atmosphere. If we account for what the cow puts into the atmosphere, the logical next step is to account for what it returns to the system.

Grass contains nitrogen, phosphorus, potassium, and other nutrients. Cattle consume those nutrients, and much of them eventually returns to the land through urine and manure. Manure is therefore not simply a waste product. It is part of the nutrient cycle and has fertilizer value. When nutrients returned by livestock replace nutrients that would otherwise have to be supplied by manufactured fertilizer, that substitution belongs in a complete environmental assessment. This is particularly relevant for nitrogen because manufacturing synthetic nitrogen fertilizer requires substantial energy and generates greenhouse gas emissions.

The biological cycle is therefore more complex than grass → cow → methane. A more complete representation is grass → cow → beef + methane + manure → soil nutrients → new grass.

This does not mean that manure should receive an automatic environmental credit. Nitrogen can be lost through volatilization, leaching, and nitrous oxide emissions, while manure itself can produce methane. Those emissions need to be included. At the same time, fertilizer production, avoided through effective nutrient recycling, should not be ignored.

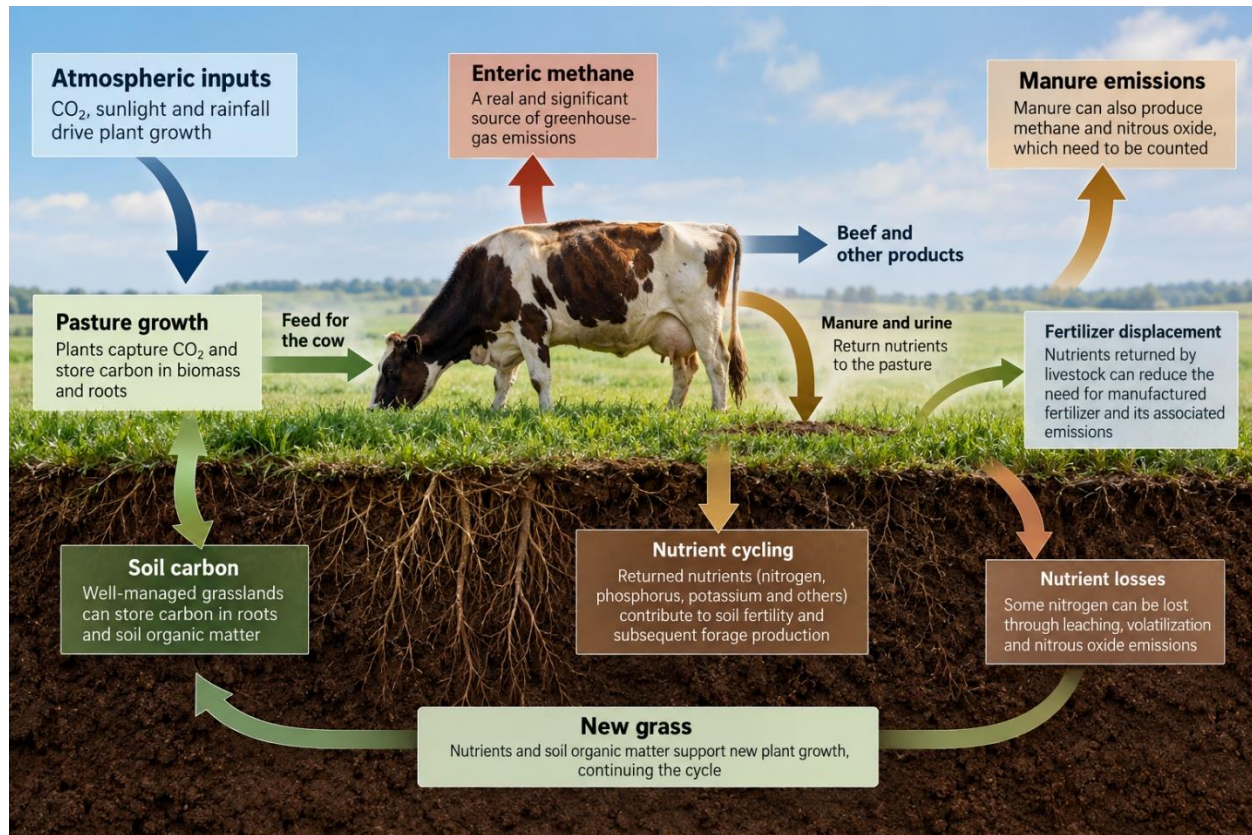


Figure 1. The grass–animal–soil system. A complete assessment includes enteric and manure emissions together with nutrient recycling, fertilizer displacement, soil carbon change, and food production.

Putting numbers into the discussion

A Portuguese life-cycle study of beef production provides a useful example. Depending on the production system, the Portuguese study estimated enteric methane emissions at 0.37 to 0.48 kilograms of methane per kilogram of beef. Using a GWP100 of 27 for biogenic methane, this corresponds to 10 to 13 kilograms of CO₂ equivalent per kilogram of beef from enteric methane alone.

That is a significant climate cost, but it is not the complete footprint. It does not tell us how much nutrient value is returned through manure and urine, how much manufactured fertilizer may consequently be displaced, or what is happening to carbon in the soil.

An especially relevant example comes from permanent pasture on Terceira Island in the Azores. Researchers studying the contribution of grazing-animal excreta to the pasture nitrogen cycle estimated that excreta supplied 65 kilograms of mineral nitrogen per hectare.

We cannot assume that all 65 kilograms are equivalent to 65 kilograms of synthetic fertilizer. Some nitrogen will be taken up by plants, while some will be lost through leaching, volatilization, or nitrous oxide emissions. Nevertheless, the finding demonstrates a critical point: grazing animals do not simply remove nutrients from pasture. They also return substantial quantities of nutrients that can contribute to subsequent forage production.

Then comes the soil.

Soil carbon may be one of the largest variables in the grazing equation. Well-managed grasslands can accumulate carbon in roots and soil organic matter, while poorly managed systems can lose carbon. For that reason, soil carbon should be measured rather than automatically assigned as a credit to grazing cattle.

A long-term study published in 2026 followed adaptive multi-paddock grazing in the Upper Midwest for approximately 11 years. The researchers estimated soil-carbon accumulation of about 0.52 tons of carbon per hectare per year. When soil-carbon change was incorporated into the life-cycle assessment, the resulting beef footprint was approximately 17 kilograms of CO₂ equivalent per kilogram of carcass weight. Including soil carbon reduced the calculated footprint by one-third to two-fifths compared with the corresponding baseline systems.

The magnitude is important, but so are the limitations. It does not mean that every grazing pasture will accumulate 0.52 tons of carbon per hectare annually. Soil type, climate, rainfall, previous land use, grazing intensity, and management all influence the outcome. The key point is that when soil carbon is actually increasing, the change can be large enough that excluding it materially alters the calculated environmental footprint.

Grazing and confinement require the same accounting.

Comparisons between grazing and confinement need to be made at the system level. A confined animal can be highly efficient at converting feed into beef, and in some circumstances feedlot beef can have lower greenhouse gas emissions per kilogram of meat than slower-growing grass-fed beef. However, the feed consumed in confinement also carries an environmental history. Grain and other feeds require land, fertilizer, machinery, processing, and transportation, while manure must be collected, stored, and eventually redistributed.

A grazing animal harvests forage directly and returns much of the nutrients consumed to the same ecosystem. That does not automatically make grazing superior. It means that neither

production system should be evaluated by selecting only the component that makes it look best. The appropriate comparison extends from production of the feed or pasture through the finished kilogram of beef.

Methane also behaves differently.

Methane itself deserves careful interpretation. It is a powerful greenhouse gas, but it is short-lived in the atmosphere, with the IPCC estimating an atmospheric lifetime of roughly 12 years. Fossil carbon dioxide behaves differently because carbon released from fossil fuels can remain in the climate system for centuries.

This distinction does not make methane harmless or eliminate the need to reduce emissions where practical. It does mean that methane and fossil CO₂ behave differently over time, and converting both into a single CO₂-equivalent value does not describe every aspect of their climatic behavior. This becomes particularly relevant when evaluating stable livestock populations rather than rapidly expanding ones.

Counting the entire system

A complete assessment of cattle production therefore has to include enteric methane, manure methane and nitrous oxide, feed production, fertilizer, fuel, and transportation. But the other side of the biological system also needs to be measured: nutrients returned to the soil, manufactured fertilizer displaced through nutrient recycling, organic matter returned to the soil, measured changes in soil carbon, and the food produced.

The examples illustrate why this matters. In the Portuguese beef systems, enteric methane alone represented approximately 10 to 13 kilograms of CO₂ equivalent per kilogram of beef. In a separate 11-year U.S. grazing study using carcass weight as its functional unit, incorporating measured and modeled soil-carbon accumulation reduced the total net greenhouse-gas footprint by 34% to 41%, to approximately 17 kilograms of CO₂ equivalent per kilogram of carcass weight.

The climate impact of grazing cattle has to be understood from the entire grass–animal–soil system.

None of these numbers demonstrates that cattle are climate-neutral, nor do they justify ignoring methane. They demonstrate something more useful: methane alone does not describe the environmental balance of a livestock production system.

A grazing cow is both an emitter and a recycler. It consumes nutrients and returns nutrients, produces food from forage humans cannot consume directly, and interacts continuously with the soil and vegetation supporting it. Under some management conditions, the pasture may accumulate carbon; under others, it may lose it. Those outcomes have to be measured rather than assumed.

Further reading

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