Reducing the environmental impact of global diets

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Abstract

It is well established in the literature that reducing the amount of meat in global diets would reduce the environmental impacts of food production. However, changes to livestock production systems also have significant potential to reduce environmental impacts from meat production, and yet are not as widely discussed in the literature. Modern, intensive livestock systems, especially for beef, offer substantially lower land requirements and greenhouse gas emissions per kilogram of meat than traditional, extensive ones. The land sparing potential of beef sector intensification is especially relevant for high priority conservation regions like the Brazilian Amazon. Leveraging livestock production systems in addition to dietary change greatly expands the opportunity to achieve conservation and climate goals in the coming decades.

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Agriculture is a key driver of environmental impacts including land use change, greenhouse gas (GHG) emissions, water use, and pollution. Livestock production is responsible for a large share of these impacts, using almost one-third of global land area (Steinfeld et al., 2006) and livestock production is responsible for a large share of these impacts, use change, greenhouse gas (GHG) emissions, water use, and pollution.

Within the livestock sector, beef production plays an outsized role in environmental impacts, accounting for 41% of livestock sector emissions (Gerber et al., 2013). Cattle also have a larger land footprint than pigs or chickens due to their need for pasture area for grazing. While pasture is also used for other ruminant species, cattle represent 82% of global ruminant meat production (FAO, 2017). Pasture expansion for cattle grazing is a major driver of deforestation in high-priority conservation regions like the Brazilian Amazon (Barona et al., 2010). In addition to contributing to land use change, cattle grazing can have significant direct negative impacts on terrestrial and freshwater ecosystems (Beschta et al., 2013; Batchelor et al., 2015).

Human diets impact the global environment since they drive demand for agricultural products. The relative share of animal products in future global diets will be a key determinant of environmental outcomes, and there is extensive literature demonstrating how reducing meat consumption could lower GHG emissions and spare land (Tilman and Clark, 2014; Harwatt et al., 2017). Dietary changes like substituting poultry for beef could also improve environmental outcomes (de Vries and de Boer, 2010), as would substituting fish or dairy for terrestrial meat (Scarborough et al., 2014).

However, given the scale of livestock's environmental footprint and projected growth in meat demand, efforts to reduce consumption will not suffice on their own. Improving the environmental efficiency of production systems is also important, but has received less attention from the conservation community. Though often criticized for its higher use of inputs, more intensive livestock production systems can in fact generate significant environmental savings. Intensive livestock systems are characterized by a concentrated and carefully controlled production environment, the use of nutritionally optimized commercial feeds, and the application of advanced animal husbandry and breeding techniques, all of which serve to produce larger animals faster than in traditional extensive systems. The increased productivity also means that for key metrics including land use and GHG emissions, intensive meat production generates fewer environmental impacts per kilogram of meat, most dramatically for beef.

The environmental gains from intensification can be impressive. For beef production, the key distinguishing feature of intensive systems is the use of grain-based feeds to fatten cattle up in the last few months before slaughter (in extensive systems cattle graze only on pasture). Finishing cattle on grain significantly accelerates growth and reduces the time to slaughter, which also serves to dramatically reduce methane emissions from enteric fermentation (Pelletier et al., 2010). The result is that intensive beef production with grain-finishing produces significantly less greenhouse gas emissions per kilogram of meat than traditional grazing-only beef systems (Fig. 1).
The emissions intensity of pork and poultry are much lower than beef, and plant-based proteins outperform all meat types (Fig. 1). More intensive production of pork and poultry can also result in decreased emissions at the farm level since animals mature faster and the nutritionally-optimized feeds reduce emissions from manure (Gerber et al., 2013). However, the additional emissions from land-use change for feed production can outweigh the on-farm emissions savings if feeds are sourced from deforestation regions (Gerber et al., 2013). Intensiﬁcation of pork and poultry production thus does not offer the same emissions savings as with beef, but intensive systems have already become widespread globally in response to rapidly growing demand.

In addition to GHG emissions, land use is a key environmental metric with which to compare different protein sources and production systems. Plant-based proteins have a lower land intensity than meat (Fig. 2) since they use the crop directly; meat production converts crop energy into animal protein, which involves inherent metabolic losses. As with emissions, pork and poultry perform better than beef in terms of land use per kilogram of meat (Fig. 2). Pigs and poultry do not require large grazing areas like cattle do, and as monogastric animals they are also more efficient feed converters. In all pork and poultry systems, nearly all land use is for feed crop production, rather than land for the animals themselves (de Vries and de Boer, 2010).

With beef production, feed finishing of cattle accelerates the growth process and allows more beef to be produced per unit grazing area. Even when cropland area for feed production is included, intensive systems using grain-ﬁnishing have a lower land-use intensity than extensive, pasture-only systems (Fig. 2). This result has been conﬁrmed at the regional level in studies of the United States (Capper, 2012), Brazil (Kamali et al., 2016), and Italy (Bragaglio et al., 2017). Intensiﬁcation of beef production thus presents an important opportunity for land sparing. Beef demand is growing twice as fast in many developing countries as in developed ones (Alexandratos and Bruinsma, 2012) and in the last ﬁfty years, pasture area expanded by one-third in Asia and by one-fifth in Latin America (FAO, 2017). Continued pressure for beef production could continue to drive land conversion and ecosystem degradation if pasture area expands further. However, meat yields (measured as the amount of meat produced per animal) remain much lower in developing countries than in the advanced livestock sectors of North America and Europe (FAO, 2017). Intensiﬁcation could increase meat production in developing countries without expanding herd size or grazing areas.

In sum, the improved productivity of more intensive livestock systems can translate into important environmental savings for both emissions and land use, most notably for beef. However, highly intensive, industrial production practices also generate concerns, for example regarding the routine use of antibiotics, localized pollution from manure lagoons, and animal welfare in conﬁned animal feeding operations (CAFOs). While trade-offs do exist between improving animal welfare, reducing environmental impacts, and increasing productivity, there are also some synergies. Finishing cattle on grain, for example, does not on its own reduce animal welfare. Intensiﬁcation practices like selective breeding and modern veterinary care can dramatically improve productivity, especially in developing countries where livestock are often smaller and sicker than animals in industrialized countries. Intensive production, including in CAFOs, can be responsibly managed to

![Fig. 1. Greenhouse gas emissions intensity (kg CO2-eq per kg of product) for different animal and plant-based protein sources. Bars indicate the min/max range of results in a literature review of life cycle analysis studies (Nijdam et al., 2012).](attachment:image1.png)

![Fig. 2. Land-use intensity (m² per kg of product) for different animal and plant-based protein sources. Bars indicate the min/max range of results in a literature review of life cycle analysis studies (Nijdam et al., 2012).](attachment:image2.png)
minimize animal stress and contain environmental impacts, but policies
are necessary to ensure best practice is followed.

There will be social and political barriers to reaping the benefits of
livestock intensification outlined here. Technology availability, access
to global markets, and capital costs all present hurdles for producers
developing countries to intensify production. Feedlot systems for cat-
tle, for example, require high levels of initial capital investment and are
unlikely to be adopted in many developing countries as long as land
rents remain low and expansion is more economic than intensification
(Jannasch et al., 2002). Even if intensification can successfully take
place, policy supports are needed to safeguard the desired environmen-
tal outcomes. Achieving land sparing through intensification of the beef
sector, for example, will require robust policies to avoid rebound, since
higher livestock yields can create an incentive for further area expan-
sion (Phalan et al., 2016). Finally, consumer and societal preferences
for certain production systems and agricultural landscapes will influ-
ence how intensification plays out at the local and regional level.

Lower-meat diets have rightfully been highlighted in the literature
as a means to reduce the environmental impact of food production,
but these demand-side solutions must be accompanied with supply-
side interventions. The gap in environmental performance between
production systems has profound implications for climate and conser-
vation outcomes this century. Modern, intensive livestock systems can
reduce the land use and GHG emissions of meat production, most dra-
matically for beef. This offers an important opportunity to achieve
land sparing and reduced emissions even with projected increases in
meat demand. In the coming decades, discussions of how to reduce
the environmental impacts of food production must consider both di-
etary changes and changes to livestock production systems as pathways
to improved environmental outcomes.

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References

Revision.

Barona, E., Ramankutty, N., Hyman, G., Coomes, O.T., 2010. The role of pasture and soy-
bean in deforestation of the Brazilian Amazon. Environ. Res. Lett. 5, 24002.


between different systems. J. Clean. Prod.

Capper, J.L., 2012. Is the grass always greener? Comparing the environmental impact of
conventional, natural and grass-fed beef production systems. Animals 2, 127–143.

de Vries, M., de Boer, I.J.M., 2010. Comparing environmental impacts for livestock prod-


Tackling Climate Change Through Livestock.

Harwatt, H., Sabaté, J., Estel, G., Sorret, S., Ripple, W., 2017. Substituting beans for beef as a

and Feedlot Beef. Organic Agriculture Centre of Canada.

Kamali, F.P., et al., 2016. Environmental and economic performance of beef farming sys-
tems with different feeding strategies in southern Brazil. Agric. Syst. 146, 70–79.

Nijdam, D., Rood, T., Westhoek, H., 2012. The price of protein: review of land use and car-
bon footprints from life cycle assessments of animal food products and their substi-
tutes. Food Policy 37, 765–770.

Pelletier, N., Pirog, R., Rasmussen, R., 2010. Comparative life cycle environmental impacts
of three beef production strategies in the upper Midwestern United States. Agric.
Syst. 103, 380–389.

Phalan, B., et al., 2016. How can higher-yield farming help to spare nature? Science 351
(6268), 450–451.

Scarborough, P., et al., 2014. Dietary greenhouse gas emissions of meat-eaters, fish-eaters,

Food and Agriculture Organization of the United Nations.

Tilman, D., Clark, M., 2014. Global diets link environmental sustainability and human