Opinion paper: Livestock is at the heart of interacting levers to reduce feed-food competition in agroecological food systems

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Introduction

The future of the livestock sector is critical due to its significant contributions to global warming, water and air pollution, biodiversity loss, as well as ethical considerations on animal welfare. Beyond the evidence that a decrease in livestock production can limit its environmental footprint, livestock also plays a positive role in most agroecosystems and in feeding the world population. Along with the production of meat and milk, pasture-based systems provide a number of ecosystem services. Livestock help closing nutrient cycles at the farm and landscape level and can support crop productivity through the provision of manure in crop-livestock areas. Livestock farming generates crucial incomes at household level in developing countries and animal products provide essential amino acids and micronutrients such as vitamin B12, vitamin D, iodine, calcium, iron, and zinc. Overall, animal products contribute to 18% of global calories and 25% of global protein consumption (Mottet et al., 2017). However, this contribution, quite variable among world regions, requires using about one-third of world arable land for feed production (Mottet et al., 2017). This generates feed vs. food competition for both the use of plant biomass and for the use of agricultural land, in particular because livestock production entails large conversion losses.

Here, we show how several levers could unwind feed vs. food competition by (i) reducing total feed demand, (ii) reducing food-competing feed demand, (iii) increasing food availability, (iv) increasing animal feed use efficiency, and (v) increasing system efficiency through circular economy. We then discuss how the simultaneous adoption of these levers may lead to synergies or antagonisms in the context of agroecological farming and conclude on implications for better integration of livestock in sustainable food systems. The ideas presented in this article are based on the results from an expert-based seminar as supported by literature evidence.

Reducing total feed demand

Feed vs. food competition could be reduced by decreasing total feed demand (Figure 1). Such reduction could be achieved by decreasing the livestock population in line with a reduction in animal product consumption, especially that exceeding nutritional recommendations in industrialised countries. Dietary shifts are widely reported as key for transitioning towards more sustainable food systems and for reducing the use of food-competing feed by up to 72% (Barbieri et al., 2021).

Reducing food-competing feed demand

A second direct lever would consist in reducing food-competing feed demand. This reduction could be achieved by using new feed resources that are not edible by humans such as cover crops and grass from orchard and vineyard inter-rows. Beyond the shade provided by trees to the animals, tree foliage may be a nutritive feed resource for animal production, health and welfare as listed among the most important benefits of agroforestry (García de Jalón et al., 2018). Introducing legume or grass-legume leys in cropping systems can jointly support the production of high-quality animal proteins and increase farm nitrogen self-sufficiency. Valuing those non-human-edible forage resources through ruminant production is a major avenue to reduce feed-food competition (Barbieri et al., 2021).

Increasing food availability

Increasing food availability is in itself a way to alleviate the feed vs. food competition. The most direct way to increase food availability would consist in increasing the cropland area allocated to food production, although converting grasslands or leys to cropland would in return reduce the ecosystem services provided by grasslands to crops. However, such a lever could be avoided if (i) cropland productivity was increased by enhancing plant nutrition through optimised crop rotations (e.g., by including leguminous catch crops, decreasing nutrient losses, increasing nutrient use efficiency in cropping systems, and transferring fertility from grasslands to croplands through ruminant manure (Barbieri et al., 2021)) and if (ii) technologies to extract energy and proteins from crops were improved. It was calculated that the human-edible crop energy and protein could be improved by an average of 12% and 21%, respectively, if appropriate technologies are applied to crop biomass (Laisse et al., 2019).

Increasing animal feed use efficiency

Increasing animal feed use efficiency is an important lever to save feed resources. Livestock breeding programmes can help to improve individual animal performances in that perspective. Livestock transforms human-edible crop-based energy and proteins into animal products in a rather inefficient way; for instance beef cattle consume 6-20 kg of human-edible grains to produce 1 kg of edible animal-based food (Mottet et al., 2017). While genetic selection initially aimed to maximise production criteria, a research priority is now the development of breeding programmes for (i) enhancing the digestive capacity of individuals on roughages that are not in competition with human food supply, (ii) improving their ability to deal with anti-nutritional factors that affect the digestion of legumes and leguminous seeds, and (iii) selecting traits such as residual feed intake to reduce methane emissions. The digestibility of non-edible biomass, especially of fodders, could be enhanced (i) by mixing crop species with contrasted agronomic traits and feed value, or (ii) by simultaneously or alternately grazing herbivore species on the same pastures. For instance, grazing sheep with cattle provided a ~29% gain in system productivity compared to monospecific sheep grazing (d'Alexis et al., 2014). Opportunities for enhancing feed use efficiency therefore exist both at the animal and herd levels.

Increasing system efficiency through circular economy

Finally, the feed vs. food competition can be mitigated by increasing farming and food system efficiency by implementing circular economy principles. Any lever aiming at optimising harvesting and storage practices to limit feed wastage would bring some benefits in term of feed supply. System efficiency could also be improved through circular economy principles by harnessing the use of food wastes to feed monogastrics. This could decrease the land requirement of European pork production by more than 20%, thereby saving land for the annual cereal consumption of 70 million Europeans (zu Ermgassen et al., 2016) – although this would also require changing current EU legislation on feed use. The use of insect-based products could represent an innovative source of feed for monogastrics. Finally, territorial reorganisation would be a promising pathway by bringing animals closer to feed resources. In this context, catch crop, cover crop and crop residues are key resources for ruminants, contributing to close local nutrient cycles while avoiding excess of nutrients (N, P) in high livestock density areas. Similarly, off-season crops could be valued, together or not with manure, as substrates for anaerobic digestion (for biogas production), with possible benefits for cropland fertilisation by using high quality digestate.

Interactions among leverage tools

Many of the above-mentioned levers to attenuate the feed vs. food competition have already been detailed in several studies. However, previous studies have missed the feedbacks that implementing those levers could have on croplands. Accounting for those feedbacks is particularly important in a context of agroecological production where many synergies between crop and livestock production are encouraged. Paying attention to the synergies or antagonisms among levers is also key to design appropriate food system scenarios. Figure 1 summarizes possible interactions and quantifies the relative contribution of each lever on crop-based food availability and crop productivity. While most previously discussed levers would lead to an increase in crop-based food availability, they can have contrasted effects on crop productivity. For instance, a decrease in livestock population would reduce high quality and nutrient-concentrated organic-based fertilising resources such as farmyard manure (which accounts nowadays for about 25% of all nitrogen applied to cropland soils according to the FAO) and decrease the provisioning of high quality food (Barbieri et al., 2021). Grazing new feed resources such as intercrops or inter-rows in orchards can also provide soluble and reactive nutrients that benefit tree growth and production, which is an example of synergy. However, antagonisms may also exist: for instance increasing energy and protein crop extraction through improved food technologies would also reduce the amount of industrial by-products that can be used as animal feed.

Conclusion

What does this analysis imply for global food systems and scientific research? We believe that beyond the necessary slight reduction in global livestock population (2), the implementation of combined levers could bring many benefits for enhancing food production while improving agriculture sustainability. This is likely to deeply modify both regional agricultural organisations and global economic flows of agricultural commodities. Revising national or continental agricultural and food security policies is key to implement the different levers we reported here. Further studies exploring local and global food system scenarios should quantitatively assess the effect of the different levers presented here, and take into account their possible interactions. In these modelling studies, livestock is a key component of agroecological food systems, and a number of options exist for optimising their role in sustainable food systems.

Ethics statement

Not applicable.

Data and model availability

Not applicable.

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Authors Contributions

All authors conceived the study, developed the analysis and contributed in writing and revising the manuscript.

Declaration of interest

There is no potential conflict of interest.

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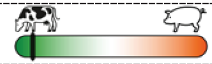
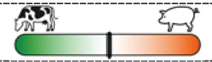
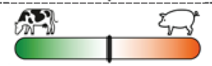
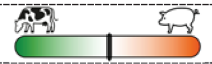
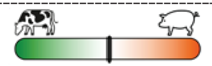
Figure caption

Figure 1 Levers to decrease feed vs. food competition and their possible feedbacks on cropland production. Levers were grouped into five main categories. The signs and the colour of each cell indicate the relative contribution of each sub-lever on crop-based food availability. A number of levers can also modify the balance between ruminants and monogastrics. This Figure is based on the results from an expert-based seminar, as supported by literature evidence.

Levers to decrease feed vs. food competition		Systemic feedbacks and interactions			
		Crop-based food availability	*Crop productivity*	*Ruminant/monogastric balance*	*Synergies and antagonisms*
1. Reducing total feed demand by reducing the density of livestock populations		+ +	-		• Higher overall protein conversion efficiency and availability for human consumption in crop-based compared to animal-based farming systems.
2. Reducing food-competing feed demand	Exploit novel feed resources (cover crops, fodder resources covering inter-rows in orchards, etc.)	+	+		• Grazing of permanent inter-rows and off-season cover crops with gain of N fertilisation efficiency. Legume crops would increase farm protein self-sufficiency. • lower manure collection for cropland fertilisation
	Optimise fodder' harvesting and feed use	+	+/-		
	Increase the share of temporary fodder in agroecological crop rotations	- -	+		• Legume crops would increase farm protein self-sufficiency.
	Switch from monogastric to herbivore production	+	-		• Decreasing ability to efficiently manage and apply manure to cropland soils as animals are less kept indoors • Synergies with increased technological ability to extract crop-based food (lower supply for by-products for ruminants)
3. Increasing food availability	Optimise cropland productivity	+	++		• Possible synergies with improved management of limited manure resources
	Optimise crop-based and animal-based food extraction	+	+/-		• Lower feed resource if lower by-product production
4. Increasing animal feed use efficiency	Livestock breeding programs	+	+/-		• Possible synergies with increasing feed-use efficiency on novel feed resources. • Strengthening the role of grazing can interfere with the organisation and efficiency of the dairy industry
	Maximise fodders digestibility (plant genetics and fodder composition)	+	+/-		• Possible antagonism: lower nutrient supply in manure to fertiliser cropland soils
	Optimise interactions among animal enterprises	+	+/-		• Possible synergies with the exploitation of novel feed resources (i.e mobile housing units for grazing)
5. Increasing system efficiency through circular economy	Maximise the use of food industry by-products and valorise food waste resources and insects-based feed	+ +	+/-		• Trade-off between an increased crop-based food extraction and livestock ability to use by-products
	Increase animal capacity to use non arable lands and rangelands	+	-		• Possible antagonisms with the optimisation of cropland productivity
	Optimise manure recycling efficiency through anaerobic digestion	+/-	+		• Using plant-based resources for co-digestion with manure could decrease plant-based food production