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Opinion paper: The role of livestock in a sustainable diet: a land-use perspective

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In 2000, the Food and Agricultural Organisation (FAO) projected that global demand for animal source food (ASF) would double by 2050 (Alexandratos and Bruinsma, 2012). Although these projections were revised slightly during recent years, they form the basis of many scientific and policy documents related to livestock production. Those projections, however, are based on global trends for a growing population and increasing incomes and urbanization, but not based on ensuring global nutrition security in a sustainable way. Currently, the world's livestock sector adds to the total anthropogenic emissions of greenhouse gases and competes for scarce resources, such as land, water and fossil energy. Without changes to reduce the environmental impact, concerns about the environment will only increase further.

We asked ourselves, how and why livestock production is essential and what would be the proportion of ASF in human diets to ensure nutrition security in a sustainable way? As land is a strict limitation of nutrition security, we took a land-use perspective, irrespective of socio-economic or technical constraints. In 2012, about 4.92 billion ha was used for agriculture, of which about 70% was used for livestock production, mainly for pasture and production of feed crops (FAO stat). Of the 4.92 billion ha of agricultural land about 1.56 billion ha is used for crop production. Assuming 9.7 billion people in 2050, then about 0.16 ha of cropland is available per person. Production of a vegan diet, for example, requires about 0.14 ha/person. Expanding the area for crop production will lead to loss of grazing areas or deforestation in the tropics, for example, resulting in loss of biodiversity and increased carbon emissions. High productive croplands, therefore, must be used to produce human food instead of livestock feed. No matter how efficiently food is produced, direct consumption of cereals by humans is more efficient ecologically than consumption of livestock fed these cereals.

Should we shift, therefore, to vegan diets? Not necessarily! Grass-based ruminant systems on marginal land, that is, land not suitable for crop production, produce human digestible protein more efficiently than food crops (Van Zanten *et al.*, 2015a). Furthermore, compared with a vegan diet, consumption of a small amount of ASF reduced land use per person when livestock were mainly fed with co-products (Van Kernebeek *et al.*, 2015).

In addition to biomass from marginal land and co-products, livestock can also upgrade two other biomass streams that humans do not currently consume: crop residues and food waste. Using crop residues as livestock feed, however, can lead to depletion of soil organic carbon, and, therefore, should be left on the field. To be safe, we assumed all crop residues are left on the field. We focus, therefore, on the potential of livestock to convert co-products from human food, food waste and biomass from marginal land, referred to as 'leftover streams,' into high-quality ASF. Livestock that eat these leftover streams do not compete with humans for cropland, and, therefore, contribute to sustainable nutrition security. By feeding only leftover streams to livestock, the number of humans fed per hectare is maximized. How much ASF can we consume, however, when we want to avoid feed–food competition by feeding only leftover streams to livestock? To illustrate that we can produce a sufficient amount of ASF, we calculated amount of ASF produced from co-products and food waste, and amount of ASF produced from 100% grass-based systems.

Amount of ASF produced from co-products and food waste depends on availability, which depends on consumption patterns of humans. If the 1.56 billion ha of cropland is used for human food production, people consume a vegan diet because no cropland is used for feed production. Consumption of a vegan diet requires annual production of about 129 kg co-products/person (see Supplementary Material S1). We chose those food ingredients in a vegan diet, whose co-products had a high nutritional value for livestock. We assumed, for example, that oil production originates from soy cultivation resulting in soybean meal. Soybean meal compared with other co-products from oil processing, for example, sunflower meal, has a high nutritional value for livestock. This assumption not only has an

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impact on the final protein production from pork, but also demonstrates the importance of optimizing crop production based on food and feed use.

During production and consumption of food, furthermore, about one-third is wasted (Gustavsson *et al*., 2011). Reducing food waste, has greater environmental benefits than feeding food waste to livestock. We assume, nevertheless, that 10% of our food will be wasted, resulting in 46 kg annual food waste/person, which can be used as livestock feed (see Supplementary Material S1). Most wasted food and some co-products have high digestibility and nutritional value for ruminants (e.g. cattle) and monogastrics (e.g. pigs). Using products with high digestibility, however, is more desirable for monogastrics than for ruminants, because enteric fermentation is lower for monogastrics then for ruminants. Through use of co-products and food waste from an average vegan diet, we are able to fatten annually about 0.42 growing pig/person. Based on an average final BW of pigs of 116 kg, about 71 g pork containing 14 g protein/person per day can be consumed (see Supplementary Material S1 for calculation).

In addition to food waste and co-products, biomass from permanent meadows and pastures can be valued by livestock, more specifically by ruminants, from production of milk or meat or both. Some of permanent meadows and pastures are on marginal land because of rainfall, temperature or terrain limitations. There are about 1.6 billion ha of marginal land, based on Global Agro-Ecological Zone (GAEZ) (Alexandratos and Bruinsma, 2012). If we use marginal land for production of ASF, we can produce daily about 3 g of protein/person. Production of 3 g protein assumes that we have 100% grass-based systems, livestock density of 0.5 tropical livestock unit (TLU)/ha, and protein production of 14 kg/TLU per year (see Supplementary Material S1). On a global scale, producing biomass from marginal land appears to be of less importance than producing protein from co-products and food waste. On a local scale, however, marginal land can play an important role, for example, in food security in smallholder systems in developing countries.

Only part of the total area of permanent meadows and pastures is on marginal land. If we use the total area of permanent meadows and pastures for production of ASF, we can produce daily about 7 g of protein/person (see Supplementary Material S1). Based on GAEZ, about 1.4 billion ha currently used for grazing has potential for crop production. The purpose of this 'grazing land,' however, is debatable. If 0.16 ha/person is insufficient to produce enough food to provide the world population a vegan diet, part of 1.4 billion ha currently used for grazing must be transformed to cropland for food production. Of the 0.16 ha/person, about 0.14 ha is needed for the production of a vegan diet, which accounts for only 10% food waste and does not include, for example, the production of cotton for clothes (see Supplementary Material S1). The area needed for crop production, furthermore, depends also on future developments of crop yields.

If, however, 0.16 ha/person is sufficient to produce enough food and other human needs then we have three options for the grazing land. First, we can continue the current practice of maintaining grazing systems, partly supplemented with concentrates. Second, we can increase production of ASF per hectare by transitioning from grazing systems to mixed crop-livestock systems. Third, we can use the land for purposes other than food production, for example, nature conservation, bioenergy or both. The amount of protein that can be produced from the total area of grazing land while avoiding feed–food competition, therefore, depends on the number of people to be nourished and production system chosen. In any case, a production of 7 g of protein from ASF per person per day seems to be feasible.

To sum up, in total about 21 g of protein from ASF can be produced person per day. The recommended intake of protein is about 60 g/person per day, from which about a third is recommended to be from AFS. These 21 g from AFS is produced without competing with food crops for arable land. We can satisfy, therefore, the daily recommended intake of protein of an average global person while avoiding competition for land between feed and food production.

What does this conclusion imply for the current situation? In practice, co-products and biomass from marginal land are already used. Co-products are used in animal diets and parts of marginal land are used by grass-based systems, sometimes so intensively that grasslands are degraded by overgrazing. Food waste is the main unused source of leftover streams, which is of interest because of its high nutritional value. Use of food waste is prohibited in many countries, including European countries, because of problems of health safety issues related to, for example, foot and mouth disease, African swine fever and Bovine spongiform encephalopathy. Besides health safety issues, we should consider also alternative applications of food waste. In the Netherlands, for example, food waste is currently used for anaerobic digestion to produce bioenergy, which is used to replace fossil energy. It is more effective, however, to replace fossil energy with wind or solar energy than with bioenergy and to use food waste instead for livestock feed (Van Zanten *et al*., 2015b). The FAO also recognizes the importance of using food waste and, therefore, started an e-conference: 'Utilization of food loss and waste as well as non-food parts as livestock feed.'

To avoid feed–food competition, therefore, future innovations should focus on shifting diets, and on adapting livestock systems to use co-products, food waste and biomass from marginal land in livestock feed. To avoid feed–food competition consumption patterns in mainly developed countries must change. The average protein intake is, for example, about 61 g of animal protein/person per day in the EU. To reduce the consumption of ASF a transition route is, therefore, required. Furthermore, innovations are needed to overcome food safety problems and technical concerns related to collecting the leftover streams. Livestock systems should change their focus, therefore, from increasing productivity per animal toward increasing protein production for humans per hectare, which means making optimal use of leftovers. Feeding mainly leftovers may require changes in breeding and feeding strategies, and changes in livestock housing

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systems. Optimal use of leftover streams enables the livestock sector to produce protein while avoiding competition for land between feed and food production and, therefore, makes an important contribution to future sustainable diets.

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Supplementary material

To view supplementary material for this article, please visit http://dx.doi.org/10.1017/S1751731115002694

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