**Livestock in a circular European food system**

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Food production systems have an immense and extensive impact on the crucial Earth systems. One promising future redesign, which is gaining increased attention, are circular food systems. In circular food systems, the use of plant biomass for human consumption is prioritized to meet human nutritional requirements (as such, losses are avoided when transforming plant-based calories or proteins into animal-based calories or proteins). Furthermore, waste is minimized – i.e. food waste, by-products, crop residues, human excreta and overconsumption of nutrients. If avoiding waste is not possible it should be utilized (recycled) in the most sustainable way. For example, during food processing, by-products such as potato peals, wheat middling’s or soybean meals are produced. If these by-products are used as a fertilizer, the use of artificial fertilizer will potentially decrease, while if by-products are used as feed for farm animals, inedible biomass for humans will be transformed into e.g. valuable food and manure.

We used a biophysical data driven optimization model to explore the effects of adopting such different circularity principles in the EU27+UK. We showed that redesigning the European food system based on circularity principles could bring environmental benefits for Europe and the world. Agricultural land (arable land and cropland) can be reduced by 71% and greenhouse gas emissions by 29% per capita while producing enough healthy diets within a self-sufficient European food system. Healthy diets are defined by securing enough nutrients on a daily basis but also includes food intake recommendations to avoid overconsumption of foods that are linked to dietary diseases.

The effect on livestock is significant: beef cattle is reduced by 91%, pigs by 78%, broilers by 79% and layers by 33% while dairy and fish show relatively small changes. Feed-food competition is largely reduced and the feed of the animals contain of food losses and waste, grass, by-products and fodder crops produced in rotation with edible-crops. The share of food losses and waste in animal feeds largely differs across animal types: from zero in ruminant feed to large shares in fish and monogastric feeds. Although animal numbers are largely reduced, their role remains important in terms of providing essential nutrients (e.g., vitamin B12). The consumption of animal-based proteins would be around 40% versus 60% plant-based proteins. The overall reduction in animal-protein intake per capita is around 50%, i.e., from 49 g per person per day to 24g per person per day.

To conclude our work shows that the combination of avoiding overconsumption and healthy eating while recycling residual food system streams has the potential to greatly improve human and planetary health. However, transitioning the EU’s food system towards circularity implies sequential changes among all its components – in other words a radical redesign of the food system.