# The Future of Animal Feed: Directions for future research and policy making

## Implications and assessment of sustainability trade-offs

The sustainability of livestock feed production is an inherently complex concept that involves the management of available land and resources, considering their optimal use for multiple objectives [Nyström et al., 2019]. The REA identifies sustainability trade-offs as the situations in which achieving a good performance in one of these objectives comes at the expense of the performance in another. Sustainability trade-offs can be found across all different hierarchical levels of the sector, from the protein crops, the farm and farming business, to the landscape and the markets. For example, shifting to landless cultivations (e.g., hydroponics, aquaculture) or moving much of protein feed production to the global North can alleviate environmental pressures of the global South and free-up land, however it may exacerbate poverty and social exclusion of south rural communities. Adopting circular agriculture alternatives (e.g., protein feed from former foods, food waste, by-products) can significantly reduce the environmental footprint of livestock feeds but can also potentially lead to large instabilities in the global agri-food market, reveal new risks for food security, and even lead to production sub-systems and markets dedicated to by-products that may generate further impacts. Overall, how can we ensure that the socio-economic gap created by the adoption of alternative protein feeds, will not be filled with unsustainable practices potentially resulting to even larger negative impacts than what conventional protein feed production generated?

Such trade-offs become particularly prominent when stakeholder objectives conflict and when there are limits on available resources to achieve sector goals (e.g., economic restrictions, issues of land availability) [Patterson et al., 2017]. Within- and across sustainability pillars trade-offs are ubiquitous in the decision-making of future alternative protein feeds. The REA proposes that all three sustainability pillars are considered equally, to enable stakeholders of the livestock sector including policy makers, farm managers, and researchers to identify and evaluate key trade-offs for the sustainable commercialisation of alternative protein feeds (Table 7).

For the assessment of such trade-offs, stakeholders need to adopt a holistic approach when evaluating agri-food system performance [Green et al., 2020]. Simulation and optimisation life cycle assessment (LCA) models, and multi-criteria decision analyses (MCDA) quantitatively evaluate the sustainability impacts associated with the various inputs and outputs of alternative protein feed production. However, because most of these alternatives have not yet been adopted at commercial scales, in combinations, and in diverse livestock systems, empirical research should generate more detailed datasets to reduce uncertainties and enhance understanding of livestock protein scenarios. Furthermore, there are no sets of reference scenarios to describe a range of plausible socio-economic futures for the agri-food sector, unlike what the global climate modelling community has established, which makes predictions even harder [Rosenzweig et al., 2016]. Another inherent limitation of these models is that agri-food stakeholders often do not behave predictably and according to economic, social or environmental rationality. For example, farmers may not necessarily invest large amounts of capital in a green technology (e.g., anaerobic digestion) even if projections show increased returns on investment and improved environmental performance [Klapwijk, et al., 2014]. Participatory approaches (e.g., interactive cognitive mapping), interviews and focus groups could help understand stakeholder behaviour, knowledge, and perception better, offering critical information for the implementation of alternative protein feeds. Regardless of developments in quantitative trade-off assessments, the final interpretation of outputs is usually left with the stakeholders and so it is imperative that their needs, concerns and vested interests are well understood to ensure that sustainability solutions are realised [Brick et al., 2018; Journeault et al., 2021]. Stakeholder objectives often change in time and with geography determining which trade-offs are more relevant, which should be considered when working towards the future of livestock feeds [Kanter et al., 2018].

**Table 7: Examples of sustainability trade-offs in using alternative protein sources for livestock feeds. The table presents recommendations for focus of future research and key stakeholders for participation in a dialogue for the better understanding of key sustainability trade-offs in the livestock feed sector.**

| Trade-off | Future research recommendations | Stakeholders' dialogue |
|---|---|---|
| Reducing land use with soilless feed alternatives frees arable land for food production and helps conserve wildlife habitats. However, if not properly managed unoccupied land can degrade quickly and lead to more fragmented habitats. | Better biodiversity indices, improved soil horizon scanning & soil organic carbon monitoring techniques. | Farmers, policy makers, local communities |
| Pest resistant GM/GE protein crops require less pesticides/herbicides leading to less chemical pollution for agricultural biodiversity. However GM genotypes they may threaten wild types due to gene transferring or displace local species. | Better understanding of GM genomes and interactions with wild types. | Researchers, farmers, policy makers, local communities |
| Using waste streams as substrates in cellular agriculture or insect farming reduces costs of production and avoids costs for waste disposal. However, it raises biosecurity concerns due to increased potential for bioaccumulation of biological and chemical contaminants from waste to human foods. | Advancements in biotechnology for better understanding of bioaccumulation pathways and detection of nanoparticles / contaminants. | Researchers, policy makers, consumers |
| Protein feeds from cellular and circular agriculture reduce industrial waste. However, they raise risks for consumer acceptability and therefore, jeopardise market viability of livestock products. | More research on relevant consumer perception and attitudes, cultural and religious barriers, retailers and industry stakeholder requirements and concerns. | Local communities, consumers, farm managers, retailers |
| Cellular and circular alternatives promote innovation in the agri-food sector leading to the development of automated, resource-efficient protein production and supply chains. However, they may have increased requirements for expensive technologies and specialised labour, which may drive smallholder feed producers out of the competition and increase unemployment. | More quantitative and accurate modelling of the socio-economic implications of large scale cellular and circular agriculture under various macro-economic scenarios | Farm managers, policy makers, local communities, retailers, consumers |

# Emerging threats within and beyond a 5-year horizon

Livestock sector stakeholders need to consider several emerging threats. Reviewing recent scientific and grey literature, the REA identifies significant socio-economic threats in the immediate and intermediate short-term (now to the next five years), due to the on-going global energy crisis, and the increased volatility of fuel and agricultural commodity prices causing instabilities in global trading. The Ukraine-Russia conflict has blocked the supply of sunflower meal from one of the largest producers globally (Ukraine) and has frozen large European investments that aimed to support Ukrainian soy production replacing unsustainable imports. Other recent geo-political developments like Brexit have exacerbated feelings of insecurity and distrust of agricultural stakeholders, as well as created concerns and instabilities in future trading partners, supply of labour, import/duty policies, agri-environmental schemes and new requirements to receive support through subsidies [Grant, 2016; Swinbank, 2017; Chang, 2018]. Political conflicts have caused significant delays in protein feed trading (e.g., delays at Ukrainian ports due to Ukraine-Russia conflict), therefore increasing the risks for biological contamination (e.g., aflatoxin) due to poor storage and transportation conditions [Zupaniec et al., 2021]. Potential disease outbreaks threatening feed and food security should also be considered with the reintroduction of PAPs for livestock feeds in Europe.

In the longer time horizon (beyond five years), climate-related impacts on global protein feed production are expected. Anticipated threats include impaired productivity and poorer nutrient profiles of conventional protein feeds, due to extreme and damaging climate-events (e.g., droughts, frost, hail) and soil degradation i.e., poor soil organic horizons due to intense agricultural activity and prolonged droughts. Finally, climate change-contaminant interactions, such as increase in mycotoxin contamination due to increased feed ingredient moisture, are expected to lead to increased outbreaks of biological contaminants and alternations in the pathways of bioaccumulation [Alava et al., 2017].

## Roadmap for future research and discussions

Like any other extensive evidence assessment, this report acknowledges specific limitations which highlight potential directions for future research and discussions. The REA captures most of the environmental, economic and social implications that are immediately relevant to FSA and the UK but are also important for global sustainable development of the livestock feed sector. It focuses on the most mature, well-established and well-explored alternative protein feed solutions as these have been identified through scientific literature, governmental reports and expert opinion. However, it acknowledges that there may be other less-known, currently under development, or yet unrecognised potential alternatives, which the REA does not consider primarily due to limitations in availability of relevant data and information. Such limitations make the discussion regarding suitability of potential alternatives at commercial scales particularly difficult. Furthermore, the REA recognises that considering the rapid advancements in the energy sector and biotechnologies, and the uncertainties in macro-economic and geo-political developments, additional sustainability implications may arise with the future implementation of these solutions at industrial scales.

Another important limitation to consider is that this report focused specifically on the use of alternative protein sources as ingredients for livestock feed; however, there may be important implications for their economic viability and overall sustainability that can be explored through a more holistic approach that considers their specific interactions with the human food chain. The report acknowledges also that while it identified key sustainability trade-offs for the implementation of alternative proteins at commercial scales, more in-depth research is required to better understand and quantitatively evaluate them under various spatiotemporal scales.

## Key recommendations for policy making

The REA synthesises four broad directions for policy making and research that may enable the potential contribution of alternative protein feeds to global sustainable development goals (Table 8) [UNDESA, 2022].

- Decoupling protein production from fossil fuel should be the first focus of policies and action in the livestock feed sector. Replacing diesel and gas with energy from renewable resources can reduce the carbon footprint of the livestock sector overall. Renewable energy prices should be regulated to ensure feed market stability, and feed producers and manufacturers should have access to energy from multiple renewable sources (e.g., solar, wind, geothermal) to allow for abundant and uninterrupted supply. This may enable sustainable adoption and unlock the full potential of alternative protein feeds that require large amounts of energy for feed processing (e.g., insect meals, food waste, former foods).

- Developing sustainable economic strategies for alternative proteins at a subnational level can help relieve great amounts of environmental pressure particularly from areas that experience issues of deforestation, land degradation, and land availability, but also a large part of the carbon footprint that is associated with transportation of feed over long distances. Local feed prices may increase due to higher labour and other input costs, but the markets should be regulated to ensure that such increases do not outweigh economic benefits from avoided import duties and transportation costs. Local solutions may need to be financially supported to avoid livestock producers turning to less expensive imported alternatives. While an economic growth of local feed markets in the North may lead to overall socio-economic development of rural communities, there may be an opposite, degrading effect for areas of the South that will lose their production (e.g., the Brazilian Cerrado), which policies should consider.

- Supporting circular livestock feed solutions such as protein from food waste, former foods, animal by-products, and industry by-products, can help reduce land-related impacts, economic costs of crop production, and tackle food waste. This requires addressing the main obstacles of customer and producer acceptability through more efficient stakeholder engagement, understanding of their concerns, and clarifying relevant misinformation and biases. Educating and supporting on-farm labour, livestock producers, and consumers with matters of feed and food security that may arise from the adoption of circular alternatives can facilitate uptake of these sustainable alternative protein sources.
- Further enhancing the feed and food regulatory system with research on more sensitive early detection and monitoring methods for feed and food security risks. This is imperative for enabling the safe adoption of alternatives like cellular and insect protein reared on waste substrates, food waste and former foods as protein sources, and processed animal proteins. Emerging feed and food security threats, like the impacts of climate change and storage/transportation conditions on biological contaminant blooms, should be considered throughout.
- These recommendations are not mutually exclusive and propose a roadmap and research agenda towards a more sustainable livestock feed production and achieving several global sustainable development goals. Immediate action is required in the coming years in reshaping the global livestock feed market to enhance its resilience against macro-economic and geopolitical instabilities (e.g., war in Ukraine, energy crisis, Covid-19 restrictions). Potential interactions between sustainable feed solutions and trade-offs within and between sustainability pillars, should be further researched to identify impacts on stakeholders across spatiotemporal scales. Anticipatory policies should be in place to compensate for losses through such trade-offs and to scope the future of the livestock sector beyond the time horizon suggested by the current sustainability agenda (i.e., 2030 as in UN SDGs). New research should adopt more transdisciplinary and co-design approaches to map the stakeholder power and potential to enable sustainable solutions for the livestock feed sector and get a better insight into the complexities of the less understood socio-economic implications. In addition, future research should investigate how the capacity of land to accommodate the production of any alternative protein sources, including the ones discussed here, changes under different demand scenarios [Shah & Wu, 2019].

**Table 8: Example of interactions between alternative protein sources for livestock feeds and global sustainable goals**

| **Sustainability goals** | **Mechanism** |
|---|---|
| Socio-economic resilience against climate-related, macroeconomic, and geo-political extreme events (SDG 1) | Decoupling protein feed production from fossil fuel and economically volatile energy sources; reduced reliance on imported protein and global trading partnerships |
| Increase food security and end hunger (SDG 2) | Landless protein sources reducing feed-food competition; increasing protein feed availability and improving accessibility through local markets; reduced protein feed costs through the use of circular agriculture alternatives leading to less expensive / accessible livestock products |
| Improve water quality and water-use efficiency, supporting the participation of local communities in water security (SDG 6) | Reduced reliance on groundwater resources for irrigation; reduced chemical pollution of water bodies by avoiding synthetic fertilisers / chemical inputs at crop production |
| Promote job creation, and safe and secure working environments (SDG 8) | More diverse labour input requirements; reduced heavy-duty manual labour compared to conventional crop production |

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| Resilience and adaptive capacity to climate-related hazards (SDG 13) & Carbon Net Zero emissions | Reduced reliance on fossil fuel, more land available for trees; healthier soil organic carbon stocks; reducing pressure on water cycle through reduced irrigation |
| Nitrogen (N) and Phosphorus (P) Vulnerable zones to reduce eutrophication pressures | Reduced use of synthetic N and P fertilisers reducing nutrient leaching; reduced organic material deposition in water bodies due to healthier / more stable soils |
| Minimise impacts of ocean acidification (SDG 14) | Reduced nitrogen leaching from soils due to the use of synthetic fertiliser |
| Ensure the conservation and sustainable use of terrestrial and inland freshwater ecosystems and their services (SDG 15) | Healthier soil horizons; reduced potential for acidification of ecosystems; reduced impacts of habitat fragmentation and degradation for terrestrial and aquatic biodiversity |
| Combat desertification, land and soil degradation, deforestation (SDG 15) | Reduced land requirements for protein crop production; reduced reliance on protein sources from environmental hotspots |
| Reducing food waste, carbon, and protecting critical water resources (Courtauld Commitment 2030) | Food waste used directly as feed or substrate; reduced fossil fuel use leading to reduced carbon emissions; landless alternatives using significantly less water |