Opinion paper: Applying agroecological principles allows assessing the multidimensionality of input-use efficiency in ruminant production systems

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Improving input-use efficiency of ruminant production systems does not always result in enhancing their sustainability and we argue that agroecology provides a conceptual framework that could help evaluate the multidimensionality of such efficiency. The definition of input-use efficiency is simple (i.e., a ratio between outputs and inputs) but hides the complexity of a broad and multifaceted concept, which encompasses multiple dimensions of ruminant production, e.g., production, environment, economic and labour. Improving one dimension of input-use efficiency such as the amount of land or labour per unit of output produced can be negatively associated with the use of other inputs such as the amount of fossil energy, concentrate feed or capital investment. For example, the sharp increase in labour productivity of EU agriculture has been associated with a decline in productivity per unit of capital invested since the 2000s (European Commission, 2016). We believe that neglecting potential synergies and trade-offs among dimensions when evaluating the efficiency of ruminant farms could exacerbate resource exhaustion, environmental degradation, social and economic inequity, food insecurity and

vulnerability to disturbances. Ultimately, this would lead to the failure of technical and scientific efforts aimed at enhancing the sector's sustainability.

Thirteen agroecological principles for the design, management and evaluation of agri-food systems were proposed by the High Level Panel of Experts for Committee on World Food Security (Wezel et al., 2020). Many of these principles relate directly or indirectly to the efficiency of agricultural production. Increasing the efficient use of conventional inputs and substituting them by agroecological alternatives (e.g., due to the complementary forage preference niche between cattle and sheep at grazing, both supplementary feed and anthelmintic treatment can be reduced) are the first two steps of an agroecological transition pathway of industrial agriculture towards a more sustainable model (Wezel et al., 2020). Agroecology aims to adapt to the local context and therefore allows different equilibria among principles (Dumont et al., 2024), which calls for assessing input-use efficiency in ruminant production systems by accounting for its multiple dimensions and their interactions. Here, we propose that the evaluation of input-use efficiency in ruminant production systems should account for five aggregated criteria derived from the 13 agroecological principles (See Supplementary Figure S1), with an emphasis on the need to simultaneously address synergies and trade-offs between them.

Criterion 1. Use animal diversity to optimise herd production efficiency

Animal diversity encompasses the genetic and phenotypic heterogeneity of individuals within and between breeds and the association of livestock species within a system. Intensive and specialised systems often neglect animal diversity by targeting a short-term efficiency, making the best use of highly-productive breeds or animals under optimal conditions. Promoting the functional complementarity of animal diversity that are well adapted to local conditions is an essential agroecological principle to stabilise herd/farm performance across time, and to buffer the effects of climatic and market fluctuations (Dumont et al., 2024). Farmer’s acceptability of increased diversity in management is a critical issue. This may, however, raise challenges because the herd will become more complex, with animals having contrasting productive and adaptive traits. Poor management can compromise the efficiency of other inputs such as labour, land or capital. Moreover, if animal diversity is valuable in a context with fluctuations and uncertainty, it can penalise overall productivity in favourable conditions. We believe a multidimensional evaluation is needed in order to optimise the trade-off between involvement of animal diversity following agroecological principles and the overall herd efficiency in the long-term.

Criterion 2. Reduce external inputs and input losses by relying on supporting services

Agroecosystems should be intentionally managed to benefit from the provision of supporting ecosystem services including photosynthesis, soil fertility, and nutrient cycling, in order to reduce the reliance on external inputs and to minimise losses to the environment. For example, managing the farm so that all forages and concentrates consumed by animals are grown on farm or on neighbouring land, and ensuring that all animal manure is used for crop’s fertilisation can reduce the need of external feed, chemical fertilisers, and manure surplus. Moreover, combining multiple plant species in grasslands and leys, and diversifying rotations, especially by including N_2-fixing legumes can increase soil fertility and plant yields, while reducing dependency on external inputs (Dumont et al., 2024). Because this approach will undoubtedly increase the complexity of farm management and become a barrier to its adoption, the impact of managing toward enhancement of supporting ecosystem services should be integrated into efficiency assessments in order to account for trade-offs with other dimensions. Such assessments will also need to distinguish between the share of production enabled by supporting services and the share that requires external inputs (e.g., via methods based on the law of thermodynamics in ecosystems such as Emergy Analysis and Cumulative Exergy Extracted from the Natural Environment).

Criterion 3. Reduce the use of human-edible feed while increasing its efficiency

Reducing the use of human-edible feeds in ruminant production is an important principle of agroecology that can unwind feed vs. food competition, and environmental impacts associated with the production of these feeds. Relying only on feed resources that are not edible by humans and grown on marginal land, however, reduces system productivity and increases enteric methane emissions. Low yield is the major reason preventing agroecology from scaling out and raises concerns on food security. Increasing the proportion of human-undigestible feed resources such as grassland in the ration can also augment labour requirements for monitoring and managing herds at pasture. We support the idea to provide human-edible feed, which are rich in nutrients and energy, only to the right animal type at the right moment (e.g., lactating females or growing animals at critical phases) in order to boost production and offset environmental impacts. Balancing the trade-offs with other dimensions when adopting such tailor-made feeding strategies could enhance input use efficiency in ruminant livestock farms.

Criterion 4. Increase added value and farmer’s income in relation to gross production value

Economies of scale thinking in agri-food industry has led to increase farm size, equipment, and farmer’s debt-taking. This debt-driven growth intensifies land use, worsens environmental impacts, decreases employment opportunities and makes this model heavily dependent on the volatility of input prices (van der Ploeg et al., 2019). In line with the economic diversification, fairness and connectivity principles (Wezel et al., 2020), agroecological farmers focus on maximising added value (AV) and their income from a given gross value of production (GVP), as opposed to expanding GVP per labour unit in conventional agriculture (van der Ploeg et al., 2019). Maximising the AV/GVP ratio implies that farmers should aim to i) balance resources such as labour, equipment, housing facilities and the share of croplands and pastures with herd size, and ii) optimise interactions between animal management and marketing strategies (e.g. matching animal production cycles and feeding strategies with market demand) to make the most of their financial investments. In practice, agroecological approaches like those relying on diversifying farm components (e.g. multiple livestock species, crop-livestock farms) also require re-allocation of farm resources (e.g. labour, equipment and capital) among enterprises, which may require more investments and thus reduce added values and farmer’s income. The AV/GVP ratio is important to evaluate farm economic efficiency and to keep farmers motivated for agroecological transition.

Criterion 5. Achieve system consistency so that farmer can manage their workload

Workload of current ruminant livestock farmers is heavy, despite an increasing mechanisation. This is also a concern in agroecological farms where farmers manage several enterprises and need to monitor a complex system. Agroecology does not seek to increase labour productivity but aims to deliver meaningful work and better working conditions to the farmers. However, high workload or time-consuming tasks can be major barriers to agroecological transition, especially in the farms aiming to diversify their components and activities. Managing a multi-species livestock farm, for example, can increase mental and physical workload because expertise is needed on each species, and smaller batches of animals require more frequent interventions. Increased workload can lead to simplifications of management, e.g., abandonment of sheep and cattle co-grazing as it would require specific fencing efforts. This, in turn, can undermine the benefits of diversification. Proper appreciation of workload constraint is thus a perquisite to foster agroecological transition.

Interactions among efficiency dimensions

We propose that evaluating the input-use efficiency of ruminant production farms should comprehensively consider the multiple dimensions mentioned above, including their synergies and trade-offs. Trade-offs can particularly occur when farm management aims to optimise between system's components. Mosnier et al. (2022), for instance, simulated three mixed farms: beef - dairy cattle, beef cattle - sheep, and crop - beef cattle to assess whether performances of livestock enterprises under integrated management were better than if managed separately in specialized farms. Integrating crop and cattle production within a farm decreased the purchase of concentrate feed, chemical fertilisers and nitrogen surplus. It, however, increased concentrate consumption by the herd due to cheaper and more accessible home-grown cereals. Second, mixed grazing by cattle and sheep reduced concentrate consumption without compromising production due to better valorisation of the grassland. However, reductions of environmental impacts related to lower concentrate use was partly offset by an increase in enteric methane emissions resulting from roughage consumption. Third, mixed farms smoothed the peaks of workload, as peaks for each enterprise (calving, harvest, etc.) occurred at different seasons. Mixed systems also provided higher income per work unit than the weighted average of each enterprise when managed separately. However, best performing specialised enterprises reduced their income per work unit and increased income variability when combined in a mixed farm with less profitable enterprises.

The complexity of agroecology poses challenges that may lead livestock farmers to simplify herd and grassland management practices, in a way that all the benefits of ecological interactions are not fully optimised. We believe that a holistic evaluation of interactions and trade-offs across aforementioned dimensions of input-use efficiency is essential to identify technical solutions for ruminant production systems. This should be considered among the priorities of sustainable livestock management initiatives. Building on the knowledge of such interactions and trade-offs, simplified decision-support tools, farmer co-learning networks, and adequate policy support should be developed to foster the agroecological transition.

Supplementary Material

References supporting for statements made in this paper can be found online at

Ethics approval

Not applicable.

Data and model availability statement

None of the data were deposited in an official repository.

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The authors did not use any artificial intelligence assisted technologies in the writing process.

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Declaration of interest

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