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> ENVIRONMENTAL ASSESSMENT OF LIVESTOCK SYSTEMS WITH THE EMERGY METHODOLOGY

Efficiency of extensive livestock systems in harsh environments

MATHIEU VIGNE

The livestock sector will need to provide meat and milk for a growing population, while at the same time limiting its environmental impacts. To meet this challenge, more and more studies are being conducted to identify the most efficient systems from an environmental perspective, especially those that use the fewest non-renewable resources in relation to their output.

In 2006, an FAO report thus called attention not only to the environmental damage they cause, but also to the lack of efficiency of livestock systems, especially extensive systems in developing countries, whose level of food production remains low.

Questioning this report, a recent study conducted by CIRAD in four different regions shows that extensive dairy systems in Mali can be more efficient than intensive systems in Reunion Island, and just as efficient as semi-intensive systems in western France. This result was obtained using the emergy methodology, which uses one type of unit to evaluate all the resources consumed to generate food or non-food products. This methodology takes into account the complex and multifunctional nature of livestock systems, especially extensive ones.

Emergy could be a useful tool enabling decision-makers to develop livestock policies adapted to suit individual contexts, and to thereby meet the growing demand for livestock products.

The livestock sector faces a dual challenge: increasing milk and meat yields, while reducing environmental impacts. Indeed, with population growth (9.6 billion people by 2050, according to the United Nations) and rising income levels, demand for livestock products is expected to increase sharply. Meeting this challenge implies identifying the most efficient livestock systems from an environmental perspective, in other words those that use the fewest non-renewable resources in relation to their output.

Challenging the analysis of extensive livestock systems...

> Emergy evaluates all resources used with one type of unit, and all products obtained also with one type of unit.

Studies have been conducted for this purpose, particularly by FAO, which published a report in 2006 entitled *Livestock's long shadow*. The goal of FAO was to alert governments to the environmental risks of the exponential development of livestock production systems and to recommend measures to mitigate these risks, from production through to consumption.

This report took stock on a global level of the environmental impacts of livestock production. It identified livestock systems as one of the primary causes of the most pressing environmental concerns: atmospheric pollution and global warming (the livestock sector emits 18% of anthropogenic greenhouse gases); soil degradation (it degrades 20% of land areas for the sector); water availability (it consumes 8% of all water used worldwide, and is the cause of pollution); and biodiversity loss, especially in the world's hotspots. It also underlined the lack of environmental efficiency in extensive systems, which are commonly found in developing countries. First, according to the report, these extensive systems are more harmful to the environment than more intensive systems: they emit more than two thirds of all greenhouse gases produced by the livestock sector, and occupy, for grazing, more than half of all land for the sector. Second, they produce less food than more intensive systems: half the amount of meat and a quarter the amount of milk.

> Extensive systems are more efficient than intensive systems.

These findings, which have produced much controversy relayed by the media and the industrial lobbies, are questioned by a recent study conducted by CIRAD, using the emergy methodology. This study shows that extensive systems can be more efficient than intensive systems and just as efficient as semi-intensive systems.

... using a global evaluation methodology...

> Extensive systems are less harmful to the environment than intensive systems.

Emergy evaluates the solar energy consumed directly and indirectly to produce a good or service. This quantitative analysis methodology uses a common unit, solar emjoules (seJ), to express the resources required to produce a good or service. For livestock systems, it makes a distinction between: renewable natural resources (sunlight, rainfall, wind, etc.) and non-renewable resources (land, borehole water, etc.); monetised industrial resources (concentrated feed, fertilisers, materials, etc.); and services (veterinary services, manual labour and animal labour). For production, unlike most studies, which only take into account milk and meat, it includes effluents and animal labour, which it also expresses in a common unit, joules.

The emergy methodology develops two main indicators. The first, transformity, measures efficiency. For a dairy system, for example, transformity is the quantity of resources required to produce either all products – milk, effluents, animal labour – (overall transformity), or just milk (milk transformity). The lower the value obtained, the more efficient the system. The second indicator, renewability, measures the environmental impact of the resources consumed, by evaluating the percentage of renewable resources in the total resources consumed.

This methodology was applied to the analysis of dairy systems in four regions presenting varying degrees of intensification: "extensive" systems in southern Mali, in harsh environments, using local rangelands covering vast areas, with very few inputs; "intensive" systems in Reunion Island, in stalls, with a high input of concentrated feed; and "semi-intensive" systems in Poitou-Charentes and Brittany, combining stalls, fodder crops and grazing.

The results obtained with emergy differ from those obtained using other methodologies, thereby fuelling debates underway on livestock production. Despite the low nutritional value of resources, the extensive dairy systems studied in Mali are more efficient than the intensive systems examined in Reunion Island, and just as efficient as the semi-intensive systems studied in western France: their overall transformity stands at 490 gigajoules of solar energy per joule of product, compared to 1 210 in Reunion Island, 500 in Poitou-Charentes and 410 in Brittany (Fig. 1).

These differences are explained by the type of resources consumed, especially for animal feed: the lower the level of processing for resources, the less solar energy is required to produce them, which results in greater efficiency, even if the output is much lower (almost 200 litres per cow per year in Mali, compared to more than 6 000 litres in the other regions). In extensive systems, animal feed comes from local raw resources (natural pastures and crop residues, such as straw

> **Emergy, a tool for rethinking livestock policies**

from maize, sorghum or millet) and residues from local grain processing (bran or cottonseed cake). In intensive systems, in addition to fodder, animal feed comes from imported industrial concentrates. The quantity of concentrated feed varies according to the context: it is high in Reunion Island (15.6 kg per cow per day), in order to compensate for the lack of land to produce fodder; it is lower in Brittany (4.4 kg) and in Poitou-Charentes (6.7 kg), where biomass from local pastures is abundant. In addition, extensive systems make use of livestock effluents to fertilise rangelands and food crops, whereas intensive systems mostly use synthetic fertilisers to produce fodder.

The quality of the resources consumed also has an impact on the environment. Mali, which primarily uses sunlight and biomass found in rangelands, has a renewability of 44%, while the proportion of renewable resources in the total resources consumed stands at only 24% in Réunion and 21% in western France (Fig. 2).

Figure 1. Extensive dairy systems in Mali use almost 2.5 times fewer resources than intensive systems in Reunion Island. Source: from M. Vigne, 2012

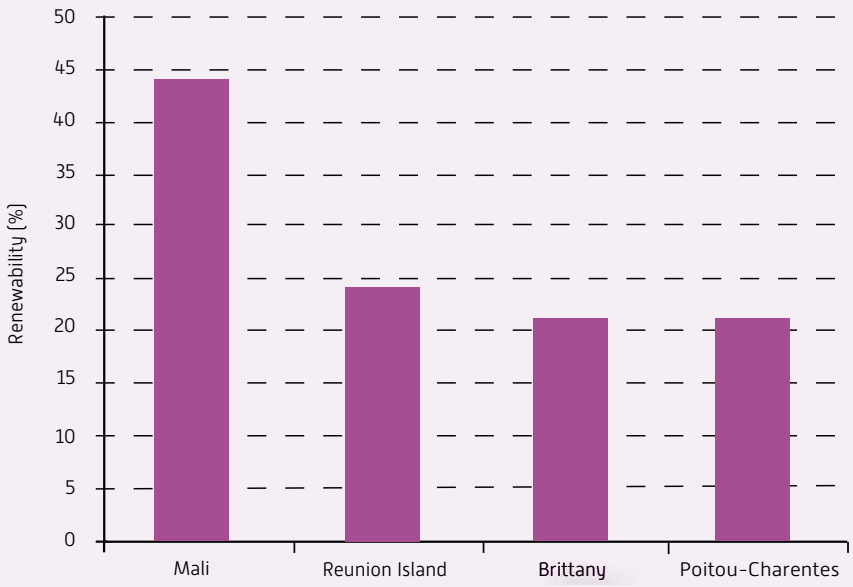

Figure 2. The proportion of renewable resources used in extensive dairy systems in Mali is twice as high as that of intensive systems in western France and Reunion Island. Source: from M. Vigne, 2012

... reflecting the many functions of livestock systems...

Contrary to the methodology used in the FAO report, emergy takes into account the complex and multifunctional nature of extensive livestock systems, especially those in West Africa. Indeed, the FAO report correlated with production several environmental indicators taken separately (water consumed, areas occupied, greenhouse gases emitted, etc.), making it difficult to assess overall efficiency. This difficulty is compounded by the hierarchy of indicators when the system is efficient for one resource, but not for another: is over-consumption of water less acceptable than over-consumption of fossil fuels, or than the consumption of more and more land?

Moreover, the FAO report compared each indicator with food production alone (milk and meat). It thereby favoured industrialised systems, which aim for high food output, to the detriment of extensive systems, which produce other goods and services.

The emergy methodology partly corrects these biases and shortcomings. By including all resources – both renewable and non-renewable –, it avoids creating a hierarchy of the resources consumed with subjective criteria. By distinguishing renewable resources, it promotes this type of resource. For example, in Mali it takes into account rangelands, which only livestock systems can utilise, and which do not therefore compete with human food. Finally, by adding effluents and animal labour to food products, emergy makes it possible to quantify a broader range of goods and services.

However, emergy fails to take into account other functions, such as savings and some environmental services. Herds are capital that livestock

A few words about...

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farmers can mobilise in case of unforeseen events, which is an important factor in providing security for families without insurance. Livestock production also provides other environmental services: through the rational management of rangelands, it regulates ecosystems by preventing the closure of areas due to bush encroachment; by introducing herds, it reopens closed areas; and by maintaining rangelands or establishing prairies, it is a source of carbon sequestration. These limitations of emergy call for further research to quantify these functions in joules.

... and providing a tool for decision-making

As it stands, however, the emergy methodology can be used to assess the benefits of extensive livestock systems in harsh environments, over and above food production, as well as the benefits of intensive systems, which are poised to play a greater role in the developing countries due to pressure on agricultural and non-agricultural land. It therefore points to ways of improving the efficiency of each system.

By comparing different systems from an environmental perspective, it provides indications about the most efficient intensification pathways in each context, and the most suitable combinations of intensive and extensive livestock systems.

Emergy is therefore a tool that could be very useful to decision-makers, especially in developing countries, for assessing the livestock sector and developing policies that are tailored to local and global changes. <

This *Perspective* is based on the findings of the doctoral thesis in agricultural science by Mathieu Vigne, entitled *Flux d'énergie dans des systèmes d'élevage laitiers contrastés: élaboration d'indicateurs et analyse de la diversité inter et intra-territoire*, which he defended in 2012 at Agrocampus Ouest. Co-financed by INRA and CIRAD, this thesis was part of the ANR EPAD project (*Efficience environnementale et productions animales pour le développement durable*) conducted by the SELMET joint research unit (Mediterranean and Tropical Livestock Systems).

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These findings have led to several publications, including:

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