Brief

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Reducing the environmental footprint of livestock production

By Aymen Frija, An Notenbaert, Yigezu Atnafe Yigezu, Veronique Alary, Amal Mannai

Photo. Environmental conservation: Women waiting to fetch water as cattle drink from a water pan in Taita Taveta, Kenya (photo credit: ILRI/ Juliet Kariuki)

“ This brief is a companion piece to the overall report “Livestock and Climate Change: Outlook for a more sustainable and equitable future”. The overall report and its associated briefs are legacy products of the CGIAR Livestock and Climate Initiative drawing from science generated during the 2022-2024 life of the research project.”

Key messages

- Environmental health and climate change mitigation and adaptation are inherently linked and need to be addressed together.

- There are many options and frameworks for sustainable livestock production, with context-specific benefits, trade-offs, costs, feasibility and scaling potential and needs.

- A range of tools and approaches are available to contextualize the right and most valuable livestock practice and management approach for a specific context.

Photo: Samburu pastoralist and his animals: A Samburu pastoralist surveys the wilderness outside his home in Kenya's Samburu region. He must buy hay to feed his livestock. Recurring droughts means there is nearly no pasture for his animals to graze. Photo ILRI/Kabir Dhanji

Introduction

Livestock production takes up approximately 77% of the world's agricultural land, or about 3.4 billion hectares, primarily for feed production. This extensive land use represents a significant opportunity cost, as it could otherwise be used to conserve biodiversity, such as wetlands and forests, produce cash and food crops or sequester carbon.

Current use limits the potential for preserving different biomes and enhancing biodiversity, leading to land degradation due to overgrazing and poor nutrient or fertilizer management. Additionally, livestock production is water-intensive and a major source of water pollution caused by run-off from fertilizers, pesticides and animal waste. As a result, livestock is considered a significant contributor to global environmental degradation, impacting climate change, land and soil health, water resources and biodiversity and altering the nutrient cycles to the detriment of ecosystem wealth at the landscape level.

Livestock farming poses significant environmental challenges, creating negative feedback loops with climate change that affect mitigation and adaptation efforts. Overgrazing damages the land, leading to poor soil quality and reduced productivity (Asner et al. 2004), while pasture expansion contributes to deforestation, destroying habitats and exacerbating climate change (Pendrill et al. 2019). Recent estimates suggest that livestock production accounts for approximately 11% of global greenhouse gas emissions, a reduction from previous estimates of 14.5% (Poore and Nemecek 2018).

In 2015, livestock agri-food systems emitted around 6 billion tonnes of CO_2 equivalent, with projections indicating that emissions could rise to nearly 9 billion tonnes by 2050 without significant interventions (FAO 2023). Agriculture contributes 40% of the global human-caused methane emissions, of which the largest part (32%) comes from manure and enteric fermentation from livestock (CCAC and UNEP 2021). Due to population and income growth, the demand for livestock is expected to increase by up to 70% by 2050 (Ranganathan 2018), which, unabated, will increase methane emissions proportionally. This environmental footprint creates negative feedback loops with climate change, affecting mitigation and adaptation efforts. Deteriorating environmental health increases the vulnerability of livestock production and societies to climate change, limiting adaptation options and reducing overall productivity, which further drives up greenhouse gas emission intensities. As global demand for animal products rises, the environmental footprint of livestock is expected to grow, worsening these challenges.

Reducing the environmental footprint of livestock production is critical to achieving global climate goals and mitigating the severe impacts of climate change and for maintaining the livelihoods of 1.7 billion people and 60% of rural households in developing countries. To address these challenges, three main pathways have been proposed (Erickson 2017; FAO, 2023b 2023c; Poore and Nemecek 2018):

- Sustainable production: Lowering the environmental footprint of livestock production
- Shifting diets: Reducing consumption of animal-sourced foods
- Reducing waste: Minimizing waste at all stages of production and consumption

This brief focuses on sustainable production practices, which are particularly relevant for the Global South. In this region, animal-sourced food consumption is much lower than in the Global North, and there are still high levels of malnutrition but also greater potential for increasing livestock productivity and production (Zheng et al. 2024; Mabhaudhi et al. 2023; FAO 2022; World Bank 2021; Paul et al. 2020). It is worth noting that most waste in the Global South occurs at the production level, whereas in the Global North, waste is concentrated at the consumption level.

Ecological sustainability in livestock systems focuses on practices that support healthy ecosystems while maintaining productive farmland (Dumont and Bernués 2014). Techniques like landscape restoration and better pasture management improve soil quality, reduce deforestation and boost biodiversity (Raes et al. 2023). These sustainable practices also strengthen the resilience of farming communities. It's important to consider gender and equity issues, as including diverse perspectives can lead to better results for everyone involved (Kristjanson et al. 2014). Efficient resource use coupled with effective waste management helps minimize environmental harm (Steinfeld et al. 2006; Chadwick et al. 2011; Gerber et al. 2013).

Focus on sustainable livestock production and management practices

A number of proposals have been put forward to support the transition to more sustainable livestock systems. These include pathways proposed by Zheng et al. (2024), Mabhaudhi et al. (2023), FAO (2022), World Bank (2021) and Erickson (2017).

Sustainable intensification of livestock systems refers to increasing livestock productivity while minimizing environmental impacts, preserving ecosystems and improving farmers' livelihoods. The aim is to improve resource use efficiency, such as feed, water and land, while reducing greenhouse gas emissions and protecting biodiversity. Sustainable intensification is based on four pillars: (i) efficiency gains (feed efficiency, reproductive performance, reduced animal mortality); (ii) crop-livestock integration through agroforestry and other crop choices that benefit soil health; (iii) reducing environmental impacts through rotational grazing, improved manure management, adoption of low-emission livestock breeds and feeds; and (iv) animal welfare and health, which can reduce disease prevalence, increase productivity and ensure long-term sustainability (Duru and Therond 2015; Dore et al. 2011).

Integrated crop-livestock-tree systems. Two recent studies exploring the need and benefits of integrating crop-livestock-trees were recently published by Mabhaudhi et al. (2023) and Peri et al. (2024). These studies show how mixed crop-livestock farming systems are common in the Global South and can be redesigned to improve system integration and sustainability for land, water, crops and livestock. Integrated crop-livestock research focuses on identifying options such as better and more affordable use of high-biomass and drought-tolerant fodder crops while improving soil organic matter through crop residues. Many of these practices improve food security and income and reduce production costs and support the transition to greater resilience to climate change by improving soil fertility and quality. In the same vein, new research on silvopastoral systems shows how integrating trees and shrubs with pasture for livestock grazing can lead to lower carbon emissions, provide shade for relief of heat stress and support biodiversity conservation. These systems also prevent deforestation and, in some cases, encourage and provide incentives for reforestation by promoting sustainable land use and preserving ecosystem services.

Nature based solutions. Examples of nature-based solutions that embody livestock or livestock systems are:

(i) managed grazing (strategically rotating livestock through pastures to allow regeneration and growth of plants throughout their cycles, maintaining soil fertility and improving nutrient cycling) (Mackie 2024; Winrock International n.d.);

(ii) Silvopasture (CBF n.d.; Mackie 2024) with a combination of trees, forage and livestock in a single system to provide shade and animal welfare, fodder and carbon sequestration;

(iii) agroforestry with integrated livestock and tree farming systems (CBF n.d.; Mackie 2024) with a combination of trees, forage and livestock in a single system to provide shade and animal welfare, fodder and carbon sequestration;

(iv) agroforestry integrating livestock into agroforestry systems to allow crops to be grown alongside trees and shrubs, with livestock grazing at the edges of plots; and

(v) regenerative livestock production; an approach that focuses on restoring soil health and carbon sequestration through rotational grazing and cover crops (FAO 2023a);

These approaches are still being explored and adapted, but they have already demonstrated the potential for livestock to work in harmony with other components of farming systems to promote resilience and regenerative landscapes.

Circular economy principles. This approach provides many advantages at the landscape level by co-benefiting the livestock and its socio-ecosystem (De Rosa et al. 2021; Harchaoui et al. 2023; Ward et al. n.d.). It can result in better feed autonomy for farmers, mostly in the south Mediterranean, by reducing the import of external feed and chemicals for fertilization and introducing cleaner production processes, mostly in the north Mediterranean, where managing animal co-products and wastes is problematic (De Rosa et al. 2021; Harchaoui et al. 2023; Ward et al. n.d.). Integrating livestock into circular economy frameworks promises more efficient environmental benefits, enhanced financial and economic viability, and increased employment opportunities (De Rosa et al. 2021; Ward et al. n.d.). This can only happen through:

(i) an in-depth understanding of the livestock systems within their landscape environments;

(ii) characterizing the existing social, economic and physical flows of goods and services across livestock and its environment;

(iii) mapping the main actors and stakeholders in these flows;

(iv) identifying technical, financial and institutional/organizational gaps across these flows; and

(v) testing how these gaps can be filled for a more robust and more integrative circular economy.

Accordingly, cross-level complementarity and synergy, emphasizing interactions between individuals, farms, landscapes as a social and environmental system and institutions is crucial for scaling up circular practices, particularly in livestock systems (De Rosa et al. 2021; Sgroi 2023).

Precision livestock farming. Another recent approach focuses on livestock precision farming, highlighting a range of technologies and practices in this category that aim to improve the efficiency and sustainability of livestock production, including data-driven decision-making, such as big data analytics to optimize livestock grazing and animal health monitoring and feed management (Khanna and Kaur 2019). Variable rate technology consists of applying variable feed rates depending on the current quality of the grazed area (Yarrington 2023). Predictive farming uses predictive analytics to anticipate livestock needs (Khanna and Kaur 2019; Yarrington 2023). This is based on real-time data that enable timely interventions in livestock management, including monitoring for disease and nutritional deficiencies (Cropin n.d.). However, many of these approaches, practices and methods face scalability challenges, with adoption rates much higher in developed countries and among large-scale farmers than among smallholders (Innovative Solutions Canada 2018). Collaborative efforts are therefore needed, especially between the public and private sectors, to improve awareness, training and financial support that can facilitate the adoption of innovations (Cropin n.d.).

Context-specific and priority setting for sustainable livestock practices

Implementing these proposals requires context-specific interventions. There are several livestock practices that emit low levels of greenhouse gases, minimize encroachment on natural ecosystems, protect biodiversity and prevent the deterioration of ecosystem services, such as integrated crop-livestock systems, improved manure management and integrating trees and shrubs with pasture for livestock grazing (Mabhaudhi et al. 2023; Zheng et al. 2024). The appropriate combination of interventions depends on the bioclimatic, agro-ecological and socioeconomic context.

In the Global South, livestock production mainly takes place on family farms. These farms vary based on geography and market access. In drier areas, agro-pastoral systems are common where livestock production is integrated with limited crop cultivation. In regions with higher agricultural potential, mixed crop-tree-livestock systems are prevalent, combining different types of agricultural production to enhance synergies.

In growing market areas, semi-specialized systems are emerging, focusing on more targeted and efficient livestock production practices. Promising approaches for these contexts include general strategies like landscape restoration, spatial targeting and land-use planning, and the enforcement of sustainable land management practices. Pasture restoration and silvopastoralism are effective methods to enhance sustainability in drier areas. Regions with higher agricultural potential benefit from practices that promote circularity and forage integration. In growing markets, focusing on input efficiency and nutrient cycling can significantly improve sustainability outcomes where the integration of various actors and practices plays a crucial role.

These solutions are not generic and can only be applied in specific contexts after taking into consideration the socioecological synergies and complementarities at multiscale levels. Therefore, a set of tools and approaches is needed to contextualize the correct and most valuable livestock practices and management approaches for a context. Several tools have been developed to prioritize and select appropriate livestock and agro-ecological interventions. One such tool is I-CLEANED, which provides a rapid and effective ex-ante assessment of environmental footprints, allowing the environmental impact of any livestock intervention to be assessed before implementation. Integrated economic and environmental cost-benefit analysis is another approach that can support a better understanding of the trade-offs associated with livestock management decisions. Vulnerability-based prioritization focuses on identifying the most urgent areas for intervention and better-allocating resources to support the sustainable transition of livestock landscapes. Life Cycle Assessment is another comprehensive methodology to evaluate the environmental impacts of livestock practices and management throughout their life cycle, from feed production to waste management. This approach helps identify areas for improvement and supports the development of more sustainable livestock systems. In addition, GIS and remote sensing can generate important spatial data that can support the development of suitability maps for specific livestock management practices and visualize land use and grazing patterns in combination with restoration options.

Capacity development and supportive enabling environment for adoption and scaling

It is essential to strengthen capacity development and sharing among national and regional partners to promote environmentally sustainable practices in livestock systems at farm and landscape levels. This includes enhancing international cooperation, which international technical organizations can facilitate by working across regions and countries for mutual learning and exchange of experiences. Such global platforms and networks will be a major source of new knowledge on best practices, research results, and technological advances in sustainable livestock production. This knowledge should take into account and incorporate local knowledge as demonstrated in pastoral systems. Developed through generations of interaction with the environment, local knowledge offers insights into sustainable land use, animal management practices and resource efficiency adapted to local ecological and cultural contexts. By integrating scientific and local knowledge, we can create more adaptable and resilient management strategies that respect traditional practices while enhancing environmental and economic outcomes.

Another fundamental aspect of these new approaches is the creation of an enabling policy environment, particularly by introducing appropriate policy incentives. These may include subsidies for farmers adopting agro-ecological techniques, carbon credits for reducing emissions and penalties for practices that damage the environment. Additionally, including livestock in Nationally Determined Contributions, Nationally Appropriate Mitigation Actions, National Adaptation Plans, and National Biodiversity Strategies and Action Plans would be crucial to aligning sectoral efforts and investments with ongoing environmental and climate goals. Stimulating existing or developing new market demand for livestock products from sustainable systems through labeling and certification schemes is another strategy that would encourage wider adoption of these practices. Finally, alternative financing schemes for long-term sustainable initiatives and practices would also be essential, especially for the transition of landscapes to agro-ecological, circular and multifunctional ones.

In addition to capacity development, wider dissemination and scaling of sustainable livestock practices require conducive policy and institutional environments. These include addressing land tenure issues, governance of communal grazing lands and other resources and creating incentive mechanisms for enhancing agro-ecological services. Past research has shown that investment in optimal policy and institutional and technological practices in livestock systems may not have high returns relative to other biomes or sectors, including cropping, forestry and water. However, the amount of ecosystem services lost due to inaction and those which can be prevented from being lost or newly generated are especially higher in pasturelands than in other biomes or land uses (Vogl et al. 2024; Yigezu et al. 2024; Yigezu et al. 2023; Akramkhanov et al. 2021; Yigezu et al. 2020). The policy implication of these findings is that even the minimum estimates of losses from degradation of natural capital in natural pastures are too high to ignore, and the cost of inaction is much higher than the cost of action. Hence, investment to reduce land degradation has high returns. The results of these studies have generated useful discussions among government officials, donors and financial institutions, including the World Bank in Tunisia and Uzbekistan, paving the way for soliciting funds and financing options to control land degradation in rangelands. This calls for generating evidence from more countries and ultimately making global estimates to show the gravity of the problems associated with inaction, create awareness at all levels and pave the way for concerted efforts to combat land degradation in livestock systems.

Implementation, monitoring and data collection for more adaptive management of livestock solutions

This area of work on systemic, sustainable, and regenerative livestock management practices is still data-poor at the landscape level and the research gap is significant. There is a need to collect more and better data to assess the extent to which livestock can be a source of restoration when well-managed and integrated across landscape dimensions (Mosier et al. 2021; Herrero et al. 2017; Thornton and Herrero 2010). This will require stakeholder involvement in planning, implementing and continuously improving these practices as well as collecting and sharing data that can be used as evidence for the broader scaling up, adoption and adaptation. Advanced tools and platforms for real-time monitoring and reporting livestock emissions and sustainability metrics are particularly relevant.

Conclusion

Adopting sustainable livestock production practices is critical to reducing the sector's environmental impacts and contributions to climate change and promoting resilience. Mottet et al. (2017) highlight how sustainable livestock production practices are the key to reducing environmental impacts and damage and call for stakeholder engagement in designing context-specific initiatives, practices and investments that support sustainable outcomes. Important progress towards sustainable livestock production systems can be achieved by focusing on context-specific interventions, facilitating stakeholder engagement and creating supportive policies and incentives (Havlík et al. 2013). Through these efforts, it is possible to balance the need for livestock products with the imperative to protect and restore our natural environment (Gerber et al. 2013) and positively impact climate adaptation and mitigation.

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