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Livestock and Climate

POLICY BRIEF

Ecosystem services and environmental benefits in livestock systems: Definition of terms, and valuation methods

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KEY MESSAGES

- Livestock systems are socioecological systems that generate different ecosystem services and environmental benefits. We have prioritized seven ecosystem services and three environmental benefits of interest.
- Integral valuation is a method that allows to assess the ecological, economic, and social value of ecosystem services and environmental benefits. Information generated from this method is amenable to benefit cost analyses for evaluating the returns on investment for introducing interventions in livestock systems.
- Knowing the integral value of the interventions allows us to demonstrate to stakeholders their economic, environmental, and social viability, and persuade them to contribute to the financing of more sustainable livestock farming models.

INTRODUCTION

Livestock plays a crucial role in national economies across the globe, forms an essential cornerstone of the global food system, and is a contributor to poverty reduction, food security, and agricultural development. It contributes 40% of the global value of agricultural output and supports the livelihoods and food and nutrition security of almost 1.3 billion people (SEBI Livestock, 2023; World Bank, 2021). Livestock production systems rely heavily on natural resources, making them significant consumers of water, land, and soil nutrients. Among all human activities, livestock production accounts for the largest land use with meadows and pastures occupying almost 26% of the global land area (Agregán et al., 2021). This extensive land use, coupled with intensive production practices, has led to substantial environmental degradation, including greenhouse gas emissions, deforestation, water pollution, and biodiversity loss (Steinfeld et al., 2006). The global livestock sector is undergoing rapid transformation, driven by globalization and rising demand for animal-source foods, population growth, and increasing wealth in many developing nations. This surge in demand is intensifying competition for finite resources, including soil, land, and water (Steinfeld et al., 2006). Simultaneously, there is growing recognition of the need for a carbon-neutral livestock sector which has amplified the pressure to manage this sector in a clean, safe, and sustainable manner (Robinson et al., 2011).

The livestock sector benefits from ecosystem services and provides them. The effects that this sector produces on ecosystems and biodiversity can be positive or negative, e.g., providing habitats for species and creating landscapes with aesthetic value, providing animal manure as a valuable source of nutrients and seed dispersal, and maintaining soil fertility in grasslands (FAO, 2023a). Ecological management practices offer a promising approach to mitigating these negative environmental impacts and enhancing the sustainability and ecosystem services supply of livestock production systems. By adopting practices such as rotational grazing, integrated crop-livestock systems, the use of cover crops, among others, livestock producers can improve soil health, water management, and pest and disease resistance, leading to increased productivity, improved natural resource efficiency, and reduced production costs. Moreover, ecological management can strengthen the resilience of livestock systems to climate change and other stressors (Pretty & Toulmin, 2011), while also contributing to food security and social equity by ensuring sustainable access to natural resources for marginalized groups (FAO, 2010).

There is still an important knowledge gap about ecosystem services and environmental benefits in livestock farming. Livestock systems based on pastures, cultivated forages, by-products of crop production, silvo-pastoral arrangements, and rangelands produce different ecosystem services and receive a variety of environmental benefits from human interventions. Our objective is to identify some ecosystem services and environmental benefits in these livestock systems, to propose an integral valuation strategy, and to incorporate these values into economic evaluation methods. This integral valuation strategy will allow us to evaluate the impacts of interventions by comparing situations before and after an intervention or between intervened and non-intervened systems. We start from the idea that livestock systems produce economic and social benefits for the population. At the same time, they offer ecosystem services and generate environmental impacts. It is possible to intervene in the livestock system, for example, by incorporating new technologies, policies, management practices, as well as institutional, cultural, and other interventions. The desirability of an intervention will depend on whether the total value of its positive impacts exceeds the total value of the negative impacts.

In this document, we present the building blocks to the development of a method for economic and environmental evaluation of interventions in livestock systems based on the integral valuation of ecosystem services and environmental benefits. We explore the relationship between livestock and ecosystem services under the theoretical framework of socio-ecological systems, we identify ecosystem services and environmental benefits produced in four types of livestock systems, and we present an integral valuation methodology and the way in which it can be incorporated into the economic evaluation of livestock production systems.

ECOSYSTEM SERVICES AND ENVIRONMENTAL BENEFITS IN LIVESTOCK SYSTEMS

A socio-ecological system is understood as a set of bio-geo-physical units that are associated with one or more social systems delimited by stakeholders and institutions (Ostrom, 2009; Martín-López et al., 2012; Glaser et al., 2008; Pallero et al., 2018). Analysis of socio-ecological systems requires the "human in nature" perspective, where human societies are embedded in the limits imposed by the ecosphere and have co-evolved with the dynamics of ecological systems. Human systems and ecosystems have been coevolving, molding and adapting together, becoming an integrated and coupled system of humans in nature (Farhad, 2012; Martín-López et al., 2009, 2012). Socio-ecological systems are characterized by a dynamic interplay between the ecological system and the social system. The ecological system offers ecosystem services, which are necessary for human life and the functioning of production and the economy, to the social system. At the same time, the social system generates positive (environmental benefits) and negative externalities that affect the natural conditions of the ecological system and its functioning (Martín-López et al., 2012). For an integrated management of socio-ecological systems, it is necessary to adopt an ecosystem approach and to elaborate proposals adapted to the social, administrative, and ecological characteristics (Pallero et al., 2018).

The villages where farmers live and produce crops, trees, and livestock are a clear example of a socio-ecological system. In the mixed crop-livestock farming village shown in Figure 1, the ecological system is made up of one or more of different natural resources including forests, wetlands, rangelands, rivers, and lakes and other water sources, not modified by human beings, and crops and/or livestock, produced by humans. In the social system, we have the producing family, whose economic activity is based on crops, livestock, or both, other families engaged in similar or different activities, associations where families cooperate with each other, families who are competing for the limited available resources, intermediaries who purchase the produce from the farming families, the final food consumers who may be inside or outside the village, and local and national governments which establish the game rules under which the actors of the social system interact.

Crops, livestock production, forestry, and rangelands have symbiotic relationships with their ecosystem because they benefit from and influence it, thereby leading to bidirectional interactions and impacts. These impacts can be positive, such us crops providing habitats to wildlife and creating aesthetic landscapes, forests helping maintain healthy aquatic ecosystems and providing reliable sources of clean water, or animal excreta serving as an important source of nutrients, facilitating seed dispersal and maintaining soil fertility in grazed grasslands. Negative externalities include pesticides that contaminate water sources, landscape homogenization which can decrease natural pollination, deforestation or poor management increasing flooding, landslides during cyclones, excess of animal excreta, poor management causing water pollution that threatens aquatic biodiversity, and overfishing those impacts ocean communities as it destabilizes the food chain and destroys the natural habitats of many aquatic species (FAO, 2023).

Ecosystem services are the multitude of benefits that nature provides to society (Millennium Ecosystem Assessment, 2005). Ecosystem services make human life possible, for example by providing nutritious food, feed, and clean water, by regulating diseases and climate, by supporting crop pollination and soil formation, and by offering recreational, cultural, and spiritual benefits (McElwee & Shapiro-Garza, 2020; Millennium Ecosystem Assessment, 2005; Philip Robertson & Harwood, 2013; Quijas & Balvanera, 2013; WWF, 2018). The annual value of ecosystem services worldwide is estimated at US$125 billion (FAO, 2023a). The supply of ecosystem services in a natural system is directly proportional to biodiversity, i.e., the more biodiversity the greater the supply of ecosystem services, which means, changes in biodiversity can influence

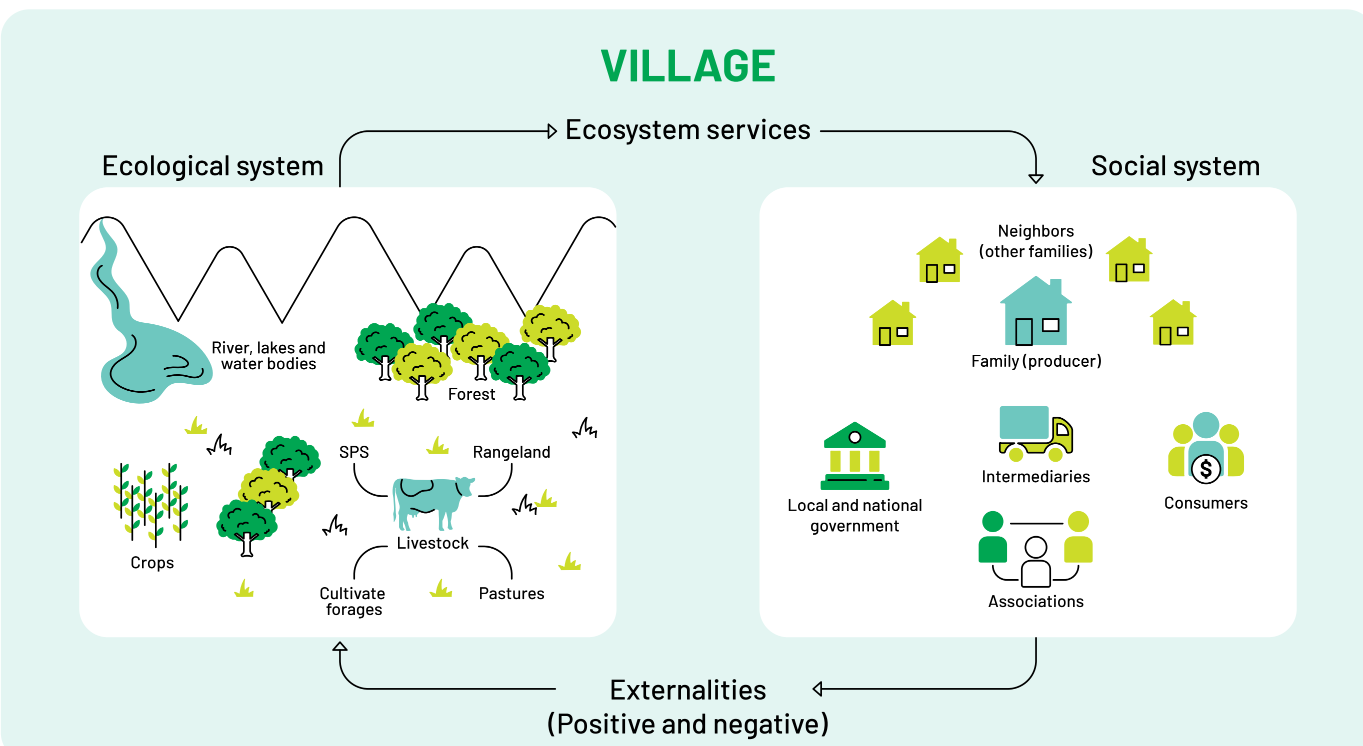

Figure 1. Socio-ecological system in the mixed farming context

the provision of ecosystem services. Biodiversity includes both diversity within and across species or ecosystems. As an important component of the ecosystem, biodiversity must be protected and managed sustainably (FAO, 2023; Millennium Ecosystem Assessment, 2005). Ecosystem services are classified into four broad categories (see Figure 2).

Livestock systems generate ecosystem services and environmental benefits. Livestock offer many goods and services to people, such as meat, milk, eggs, hides, feathers, fibers, traction, transportation, and manure. They also serve many social and financial roles in different societies since they may be raised primarily for subsistence or local sales to supply international markets with large quantities of produce, as a store of value, or as a means of increasing one's social status. The scale, purpose, and nature of the farming enterprise is known as the production system. Ruminant livestock, such as cattle, sheep, and goats, tend to be dependent directly on the land. Their production therefore is largely determined by land-use and the quality/health of the agro-ecology (FAO, 2023b). Livestock production systems can be very diverse, and this diversity is influenced by economic, geographic, environmental, and cultural factors (Diez-Gonzalez, 2007). Being a subset of agricultural systems, livestock production systems are the product of agro-ecological forces coupled with the consistent and conscious endeavor of human beings to harness various goods and services toward fulfilling several of their needs (Pandey & Upadhyay, 2022). The focus of this report includes the following livestock systems:

Pastures

Areas of land that are covered with grasses, legumes, and other herbaceous plants that are suitable for grazing animals. Pastures are typically managed for the purpose of providing feed for grazing animals rather than for cultivation. They serve as a vital component of agricultural and livestock systems, providing a source of nutritious forage for animals such as cattle, sheep, and goats.

Cultivated forages

Crops that are specifically grown for feeding livestock. Browse and herbage which is available as feed for grazing animals or for harvesting as feed (i.e., cut-and-carry, hay, or silage).

Figure 2. Ecosystem services classification

Rangelands

Rangelands are vast landscapes characterized by naturally occurring vegetation consisting primarily of grasses, grass-like plants, forbs, or shrubs suitable for grazing by livestock and wildlife (IYRP. Open Flyer, 2021). The term rangeland encompasses a diverse array of ecosystems such as grasslands, savannas, shrublands, deserts, steppes, pampa, llanos, cerrado, campos, veld, tundra, alpine vegetation, and marshes. Grasslands and savannas are the most widespread biomes within rangelands (WWF, 2021). The terms "rangelands" and "grasslands" are often used interchangeably. Rangelands may include restored and rehabilitated lands but are generally considered to be in their "natural" state in contrast to modified/improved pastures and paddocks.

Agro-silvo-pastoral systems (SPS)

Agro-silvo-pastoral systems are production systems relying on the integration of crop and pastoral livestock production, soil, crop, and tree-based adaptive management practices that optimize resources and reduce risk and vulnerability (Castro-Nuñez et al., 2021). These systems typically incorporate pastures with either widely dispersed individual trees or clusters of trees strategically placed throughout the grazing area and are recognized as essential for reducing tropical deforestation and improving livelihoods, ecosystems services, and carbon sinks.

In these livestock systems we identify and prioritize seven ecosystem services and three environmental benefits of interest (see Table 1).

INTEGRAL VALUATION

Over millennia and across the world, people have developed several ways of understanding and relating to nature and its many values. Nature's values are expressed by people and are considered in decisions, including what and whose values are involved or affected. They also introduced a typology that comprises four interrelated meanings of value or its layers (Pascual et al., 2023). An integrated valuation allows for the ecological, socio-cultural, and economic values of an ecosystem to be identified (Villegas-Palacio et al., 2016) (Figure 3). Our objective is to evaluate the impact of interventions by comparing the ecological, economic, and social value between a situation before/after or with/without those interventions. The ecological value corresponds to the physical quantities of ecosystem services or environmental benefits produced. The economic value is the monetary value of each unit of service or benefit and reflects the value generated by society that use the ecosystem service. The social value refers to the knowledge and perceptions that the population has about the services and benefits that are generated in the ecosystem they inhabit (Pascual et al., 2023; Villegas-Palacio et al., 2016).

Table 1. Ecosystem services and environmental benefits in different livestock systems

Name	Type	Pastures	Cultivated forages	Rangelands	Agro-silvo-pastoral systems
FOOD	Ecosystem service	✓	✓	✓	✓
FEED	Ecosystem service	✓	✓	✓	✓
CARBON STORAGE AND SEQUESTRATION	Ecosystem service		✓	✓	✓
MICRO-CLIMATIC REGULATION	Ecosystem service			✓	✓
SOIL FERTILITY	Ecosystem service	✓	✓	✓	✓
HABITAT FOR SPECIES	Ecosystem service		✓		✓
AESTHETIC APPRECIATION	Ecosystem service			✓	✓
METHANE EMISSIONS REDUCTION	Environmental benefit	✓	✓	✓	✓
WATER USE REDUCTION	Environmental benefit			✓	✓
LAND USE REDUCTION	Environmental benefit	✓	✓	✓	✓

We are developing a comprehensive valuation strategy for the ecosystem services and environmental benefits prioritized in livestock systems. In Table 2 we present an overview of the strategy.

In addition to the valuation proposed in Table 2, we propose to estimate stakeholders' willingness to pay for interventions that improve the supply of ecosystem services and environmental benefits in livestock systems. From behavioral economics there are two experimental approximations that can be used for this purpose: i) Discrete Choice Experiments (DCE) (Čop & Njavro, 2022; Mariel et al., 2021; Rakotonarivo et al., 2016) and ii) Public Goods Games (PGG) (Čop & Njavro, 2022; Hasson et al., 2009). Estimating the willingness to pay for these interventions will allow comparison with the intervention costs and determine whether it is possible to finance them or not.

BENEFIT:COST ANALYSIS

Benefit:cost analysis (BCA) is a structured approach to evaluating the financial viability of business decisions. By performing a BCA, management can tell whether an investment is worthwhile for the business (Harvard Business School, 2023). To determine the economic feasibility of an investment, the benefit-cost ratio (BCR) is calculated by dividing the total benefit of implementing the option by the total cost. The estimate of benefits and costs considers the opportunity cost of money represented by the interest rate. If the value of the BC ratio is greater than or equal to one, then the intervention is considered worthy. Conversely if it is less than one, the investment is considered not profitable. In livestock systems the decision is whether to implement the intervention, where the cost is the investment needed to implement the intervention, and the benefit is the increase in income and the estimated monetary value of the improvement of ecosystem services. Considering both the value of production and the value of ecosystem services and environmental benefits allows developing more complete economic assessments and improving decision making in livestock systems. The economic evaluation consists of six complementary processes, namely: i) free cash flow, ii) Net Present Value (NPV), iii) Internal Return Rate (IRR), iv) Benefit/Cost ratio (B/C), v) Repayment Period (RP), vi) Risk Analysis.

In 2023, we used the integral valuation method described above to develop three economic and environmental evaluations in Colombia: i) methane emissions reduction in a SPS (Sandoval et al., 2023), ii) reduction of carbon footprint in dairy systems with implementation of silvo-pastoral systems and improved pastures (González-Quintero et al., 2023a), and iii) reduction of carbon footprint in beef farming systems with implementation of improved pastures and good management practices (González-Quintero et al., 2023b).

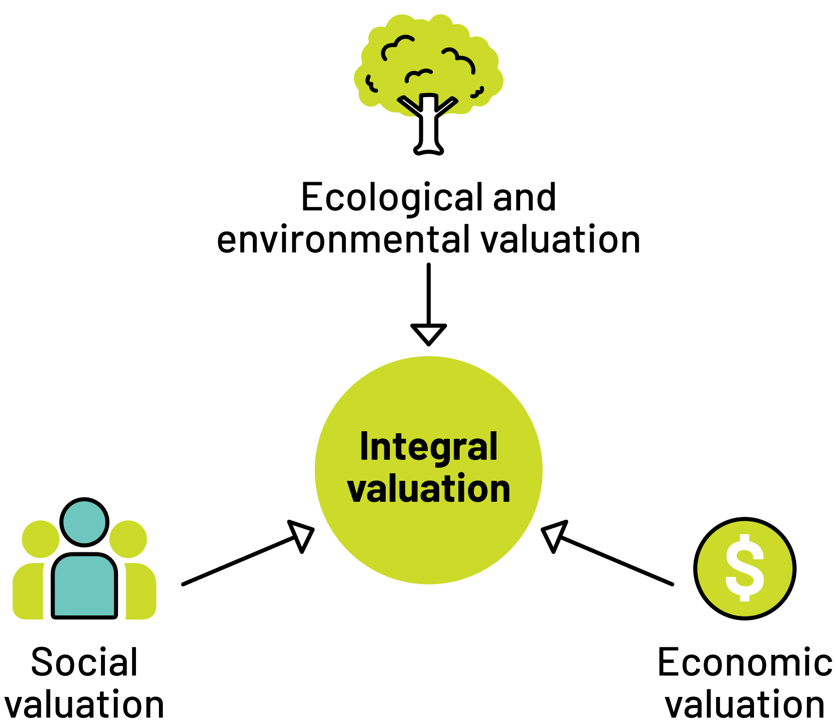

Figure 3. Integral valuation of ecosystem services and environmental benefits

Table 2. Strategy for integral valuation of ecosystem services and environmental benefits in livestock systems

Ecosystem service/ Environmental benefit	Ecological and environmental valuation	Economic valuation	Social valuation
FOOD	Product: Milk and meat. Amount of milk (lts) or meat (kg) produced per animal or hectare	The value of milk, meat, leather, feather, etc. produced. Market price or milk and meat are used.	Do you think that milk and meat are important for human nutrition? Do you consume meat, milk, or both? Rate from 1 to 5 how important you think milk and meat is for human nutrition?
FEED	Quantity of feed accessible per animal or hectare Quality of feed Seasonal availability	Market price of Forage Feed cost (60-70% of total cost)	Do you know what the feed service in livestock systems is? Rate from 1 to 5 how important you think the feed service is?
CARBON STORAGE AND SEQUESTRATION	Storage: Amount of carbon stored to date Sequestration: Annual rate of carbon capture	Market price Carbon price in Tradable Emissions Permit Systems	Do you know what the carbon sequestration service in livestock systems is? Rate from 1 to 5 how important you think the carbon sequestration service is?
MICRO CLIMATIC REGULATION	Productivity change: Comparison of animal productivity with and without shade	Income changes Increase in income derived from increased production	Do you know what micro climatic regulation in livestock systems is? Rate from 1 to 5 how important you think the microclimatic regulation service is?
SOIL FERTILITY	Identification: Nutrients available in manure Quantification: Estimation of the amount of manure in the livestock system	Replacement cost Cost of soil fertilizers that we would have to use if we did not have available manure	Do you know what the soil fertility service in livestock systems is? Rate from 1 to 5 how important you think the soil fertility service is?
HABITAT FOR SPECIES	Identification: What species inhabit the livestock system? Quantification: Estimation of the number of individuals and reproduction and death rate of each species	Willingness to pay to conserve the species Experimental approach, Discrete Choice Experiment (DCE)	Do you know what species live in your livestock system? Do you consider that this species are goods or bads for your livestock system? Do you want these species to continue living in your livestock system or do you want to eradicate them?
AESTHETIC APPRECIATION	Identification: The livestock system has a landscape that may be of tourist interest	Travel costs Cost incurred by a person who wishes to visit this livestock landscape	Do you think the livestock landscape is attractive enough to visit? Rate your experience visiting the livestock landscape from 1 to 5? Did visiting the livestock landscape generate feelings in you such as tranquility, inspiration, joy, amazement or similar? Would you recommend other people visit the livestock landscape?
METHANE EMISSIONS REDUCTION	Quantification: Estimate of the reduction of methane emissions per animal and in units of CO2 eq	Market price Carbon price in Tradable Emissions Permit Systems	Do you know what methane emissions in livestock systems is? Are you interested in reducing methane emissions in your production system? Rate from 1 to 5 how important you think it is to reduce methane emissions?
WATER DEMAND REDUCTION	Quantification: Estimation of the reduction of the water requirement of the forage. Evo transpiration is applied. Estimation of the reduction of water consumption by animals. What type of water does the requirement cover: How much green water (rain) and how much blue water (superficial)?	Market price Water price	Do you know what the water demand in livestock systems is? Are you interested in reducing water demand in your production system? Rate from 1 to 5 how important you think it is to reduce the water demand?
LAND USE REDUCTION	Quantification: Estimation of the area needed to feed an animal	Opportunity cost Opportunity cost of using land in another activity than livestock, for example for conservation, afforestation, crop production, or infrastructure	Do you know what land use in livestock systems is? Are you interested in reducing land use in your production system? Rate from 1 to 5 how important you think it is to reduce land use?

CONCLUSION

The importance of ecosystem services for livestock systems is multifaceted, encompassing livelihoods, biodiversity, water resources, cultural values, economic stability, and resilience, among others. Sustainable management of these services is paramount for safeguarding for the long-term well-being of rural communities. Integral valuation serves as a comprehensive approach to incorporating the value of ecosystem services and environmental benefits in the financial or monetary assessments of livestock systems. We identify and prioritize seven ecosystem services and three environmental benefits present in livestock systems, for which we are refining the integral valuation methodology.

There is a need to build a database for the ecosystem services provided for each type of production system. This work has started already in 2023 and will be completed in 2024 based on extensive search on already existing literature, published and unpublished data, and supported by findings from the on-going research conducted by various OneCGIAR initiatives, including Livestock and Climate. In 2024, field applications will be carried out within the framework of CGIAR projects where information can be collected. In each implementation, the ecosystem services and environmental benefits generated and the interventions to be evaluated will be identified. This exercise will allow each of the integral assessment methods proposed in this document to be described in detail, validated in the field, and generalized.

Upon completion, the generated information will serve as a valuable resource for scientists, land managers, decision-makers, and donors. This data will provide crucial support for informed decision-making on specific restoration initiatives, considering the project's objectives and the potential return on investment.

ACKNOWLEDGEMENTS

This work was carried out as part of the One CGIAR Initiative Livestock and Climate (L&C). We thank all donors who globally support our work through their contributions to the CGIAR System. The views expressed in this document may not be taken as the official views of these organizations.

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CORRECT CITATION

Flórez, J.F.; Louhaichi, M.; Yigezu, Y.A.; Abdrahmane, W.; Worqlul, A.; Hassan, S.; Belgacem, A.O.; Sandoval, D.; Junca, J.J.; Notenbaert, A.; Karanja, S.; Burkart, S. (2023) Ecosystem services and environmental benefits in livestock systems: Definition of terms, and valuation methods. Cali (Colombia): CGIAR Initiative on Livestock and Climate. 10 p.

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December 2023