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Article Review

Sustainable Systems for Livestock Production Entrepreneurship for Global Food Security: Integrating Nature-Based Solutions

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Abstract

Livestock production is integral to the global food chain with its physiological, nutritional, as well as economic benefits for billions of people around the world. At the same time, conventional livestock production has various environmental challenges such as production of greenhouse gas emissions, land degradation, water contamination, loss of biodiversity, among others. Nature-based solutions (NbS) have been recognized for their capability to address these challenges through the harnessing of ecological processes in livestock production activities. This review combines scientific literatures for sustainable livestock production strategies coupled with NbS for the purpose of understanding the roles of entrepreneurship in their scalability for balanced environments as well as financial viability for livestock producers worldwide. Various NbS approaches such as silvopasture practices, rotational grazing practices, agroforestry practices, integrated crop livestock production approaches, among others, have been highlighted in this review for their contribution to global food security, environment integrity, as well as rural economy development.

Keywords: *Sustainable livestock production, Nature-based solutions (NbS), Sustainability.*

Introduction

Global food security is fundamentally supported by livestock systems, which play a vital role in providing dietary protein, essential micronutrients, and broader socio-economic stability. Livestock-derived foods such as meat, milk, and eggs contribute significantly to human nutrition, particularly in regions where alternative protein sources are limited or less accessible. Beyond their nutritional value, livestock systems underpin the livelihoods of millions of people worldwide by creating employment opportunities and generating income across value chains, including production, processing, and distribution. This is especially evident in developing regions, where mixed crop–livestock systems are widely practiced and serve as a cornerstone of rural economies and household resilience [1,2].

Despite these benefits, the rapid intensification of livestock production has raised significant concerns related to environmental sustainability. Expanding production systems are often

associated with increased greenhouse gas emissions, land-use change, water resource depletion, and biodiversity loss. These challenges contribute to climate change and ecosystem degradation, thereby threatening the long-term viability of food systems themselves. Consequently, there is a growing need to balance productivity with environmental stewardship to ensure that livestock systems remain sustainable and resilient under changing global conditions [2,3].

In this context, nature-based solutions (NbS) have emerged as promising strategies that harness ecosystem functions to address complex societal challenges, including food security and climate change. Integrating NbS into livestock production systems offers opportunities to improve productivity while simultaneously restoring ecosystem services such as soil fertility, carbon sequestration, and water regulation. Furthermore, entrepreneurship plays a crucial role in facilitating this transition by driving innovation, mobilizing investment, and accelerating the adoption of sustainable practices. Therefore, this review focuses on examining the intersection of NbS, livestock production, and entrepreneurship as a pathway toward achieving global food security [3,4].

Materials and Methods

This review draws on synthesized literature, including research articles, review papers, and empirical studies that underpin current scientific knowledge. Priority was given to analytical and authoritative reviews covering sustainability and sustainable development, animal husbandry and livestock production, entrepreneurship, food science, food security, and nature-based solutions. Sources were obtained from reputable publishers such as Springer Nature and BMC, as well as recognized international organizations including the United Nations and the FAO. Where relevant, more recent empirical studies were incorporated to update, refine, or contextualize existing insights. The overarching objective was to integrate robust, policy-relevant evidence for a broad range of stakeholders with an interest in agriculture and animal husbandry.

Sustainability Challenges in Livestock Production

Livestock production is estimated to generate approximately about 14–18% of total human-induced greenhouse gas emissions, largely via methane from enteric fermentation, emissions from manure, and the energy and inputs used in feed production. The conversion of forests and natural habitats into grazing areas and feed cropland has also been a major driver of deforestation and the erosion of biodiversity in many parts of the world. Furthermore, inefficient nutrient management and high-water demands contribute to pollution and degradation of aquatic ecosystems. These issues are closely linked to the socio-economic constraints faced by producers. Smallholder farmers often have limited access to markets, finance, infrastructure, and extension services, which restricts their capacity to adopt modern and sustainable practices. Increasing climate variability and extreme weather events further heighten production risks, leaving producers' livelihoods and local food security more exposed. Advancing sustainable and productive livestock systems therefore requires integrated strategies and interventions that safeguard environmental integrity, strengthen economic resilience, and promote social equity. Such efforts include climate-resilient practices that improve feed efficiency, manure management, grazing systems, and agroforestry. In parallel, aligning sectoral growth pathways with climate action and net-zero objectives—through greenhouse gas measurement, science-based targets, and incentives for low-carbon value chains—can help reduce climate vulnerability while supporting producers' adaptation and long-term resilience. [2–7].

Nature-Based Solutions in Livestock Systems

Nature-based solutions integrate ecological processes into agricultural management in order to strengthen ecosystem services and the resilience of farming systems. In the context of livestock,

these approaches focus on biodiversity, soil health, and natural nutrient cycles while sustaining or even improving productivity levels. One key example is silvopasture within agroforestry systems, where trees, forage, and livestock are combined on the same land to create multifunctional landscapes. Studies show that silvopastoral systems can increase carbon sequestration, build soil organic matter, and improve animal welfare by offering shade and shelter, while trees can also provide additional income from forest products. Rotational and regenerative grazing offer another important illustration of nature-based solutions in livestock systems. By periodically moving animals between paddocks, rotational grazing allows vegetation to recover and more closely resembles natural grazing dynamics, which can boost pasture productivity, limit soil erosion, and support greater biodiversity than continuous grazing. Regenerative grazing places further emphasis on rebuilding soil carbon stocks and actively restoring ecosystem functions. A third major example is integrated crop–livestock systems, which strengthen nutrient cycling by using manure as fertilizer and crop residues as animal feed. These systems reduce reliance on external inputs, enhance soil fertility, and improve the overall resilience of farms to shocks and stresses, making them especially valuable for smallholder producers in developing regions [8–11].

Table I. Nature-Based Solutions and Their Benefits

Nature-Based Solution	Primary Environmental Benefits	Socio-Economic Advantages
Silvopasture	Carbon sequestration, biodiversity	Income diversification, animal welfare
Rotational Grazing	Soil health, reduced erosion	More efficient pasture use, resilient forage
Agroforestry Integration	Nutrient cycling, microclimate regulation	Diversified products and income
Integrated Crop-Livestock	A better nutrient cycle	Reduced input costs

Entrepreneurship for Sustainable Livestock Systems

Improved strategies are needed to advance animal husbandry, particularly by strengthening its business dimension and ensuring long-term profitability. The livestock sector must increasingly be understood and managed as an enterprise that can generate sustainable economic returns alongside environmental and social benefits. Entrepreneurship plays a pivotal role in expanding sustainable livestock systems by turning nature-based solutions into robust, market-ready business models. They drive innovations such as precision livestock farming tools, digital monitoring systems, and data-informed grazing management, which enhance efficiency while lowering environmental footprints. Entrepreneurial initiatives also help producers capture more value by developing differentiated products, using certification and eco-labels, and building shorter, more transparent supply chains that connect farmers directly with consumers. These approaches can improve income stability, reward sustainable practices, and accelerate the wider adoption of environmentally sound livestock systems [12–15].

Environment

NbS-integrated livestock systems deliver multiple ecosystem services, including carbon sequestration, improved water regulation, and habitat provision. Studies consistently show lower emission intensities and higher soil carbon stocks in diversified systems compared to conventional operations. Economically, diversified livestock enterprises demonstrate greater income stability and resilience to climate shocks, while reduced reliance on external inputs lowers production costs and supports long-term profitability. Biodiversity and wildlife conservation are essential

components of these systems because diverse plant and animal communities help stabilize ecosystems, buffer against pests and diseases, and improve adaptive capacity under climate stress. Landscapes that maintain habitat connectivity for wild species also support pollination, natural pest control, and genetic diversity, all of which underpin sustainable livestock productivity over time. By integrating wildlife-friendly practices and mixed vegetation NbS-based livestock systems simultaneously safeguard ecological integrity and strengthen the ecological foundations of food security [16–19].

Table II. Comparison of Conventional and NbS-Integrated Livestock Systems

Indicator	Conventional Systems	NbS-Integrated Systems
Carbon footprint (emissions/unit product)	High	Reduced
Soil health	Degraded or static	Improved
Biodiversity	Low	Enhanced
Farm income stability	Variable	More diversified

Challenges and Knowledge Gaps

Although the benefits are evident, the adoption of NbS is hampered by several issues such as high investment costs in the establishment of NbS, lack of technical knowledge, and the absence of incentives through policy (figure 1). Long-term research in agro-ecological zones is currently not well represented.

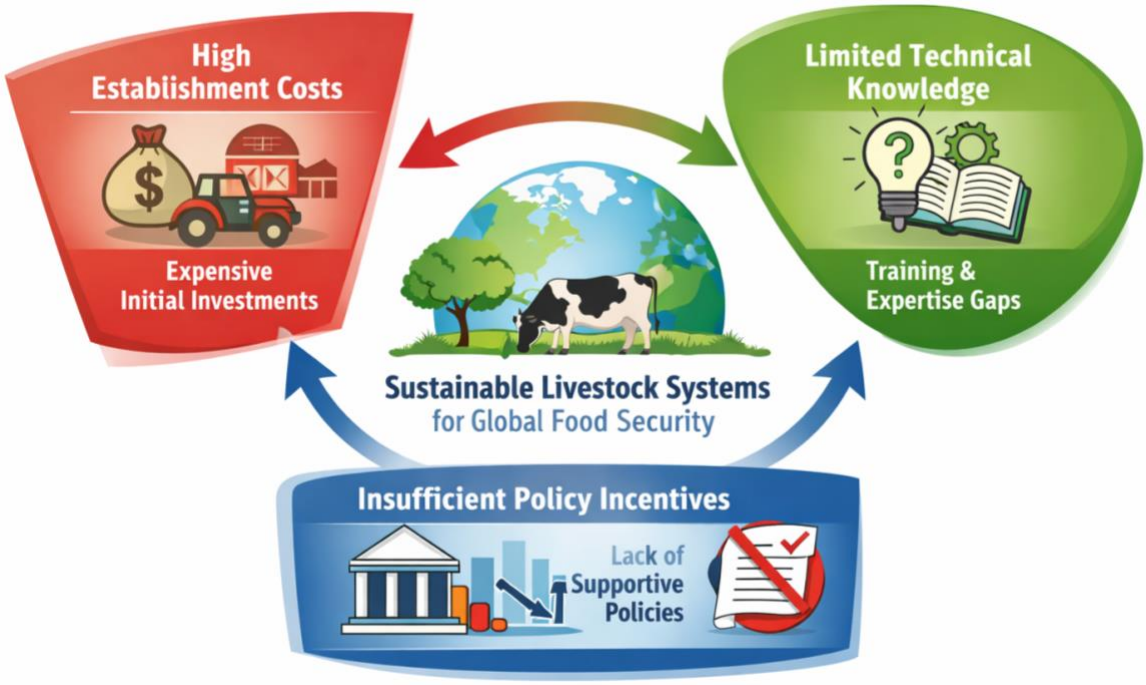

Figure 1. Challenges in Implementing Sustainable Livestock Production Entrepreneurship for Global Food Security Using Nature-Based Solutions (NbS).

Conclusion

Not all business ventures generate consistent profits, highlighting the need to restructure entrepreneurial systems across sectors to improve long-term viability. In this context, integrating nature-based solutions (NbS) into livestock production represents a practical pathway to achieving sustainable food security while simultaneously enhancing economic returns. Entrepreneurship

plays a central role in this transformation by driving innovation, facilitating wider adoption, and enabling the effective scaling of NbS-based approaches. To fully realize these benefits, it is crucial to strengthen supportive policy frameworks, encourage strategic investments, and advance targeted research that supports the development and implementation of NbS-integrated livestock systems.

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