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Review

Sustainable Food Systems Through Livestock–Pasture Integration

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Abstract: The world's population is projected to rise significantly, which poses challenges for global food security due to increased demand for food, especially from livestock products. As incomes grow in lower-income countries, there is a shift towards more diverse diets that include meat and dairy, stressing our agricultural systems. Livestock plays a crucial role in food production, contributing about 16% of dietary energy, and effective pasture management is vital for enhancing livestock productivity. This review explores how integrating pasture and livestock management can create sustainable food systems and improve nutrition and livelihoods. It assesses the economic viability of pasture-based livestock systems and examines how climate change affects both pasture productivity and livestock performance. The review also identifies innovative practices, such as improved grazing management and technological advancements, that can improve pasture health and livestock output. The findings underscore the importance of well-managed pastures, which can restore degraded lands, improve animal welfare, and support food security. It also highlights that adaptation strategies are necessary to address the challenges posed by climate change, ensuring that livestock systems remain sustainable. By focusing on innovative practices and better management, we can meet the growing demand for animal products while preserving ecosystems and promoting economic stability. Overall, this review emphasizes the need for a holistic understanding of how livestock and pasture management can work together to enhance food security in a changing world.

Keywords: food security; livestock production; cultivated pastures; natural rangelands

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1. Introduction

The world's population has grown from less than 3 billion in 1950 to almost 7 billion today. According to the latest United Nations projections [1,2], it is expected to reach 9.3 billion by 2050 and 10.9 billion by 2100. This growth presents significant challenges for global food security due to the rising demand for food [3]. Adding to this challenge is the rise in incomes, particularly in less- and the least-developed countries, where per capita income growth is expected to reach 3.7% and 4.7%, respectively [4]. This income growth drives increased demand for diverse diets, including meat and dairy, leading to greater strain on arable land and pastures for market feed [5]. For instance, projections indicate that meat consumption will increase by 75% and dairy consumption by 68% by 2050 [6]. Consequently, researchers estimate that agricultural yields must increase by 25–70% to meet the needs of a growing population [7]. Even with these suggestions, food security remains a continuing challenge. Over the past three decades, approximately 800 million people have continued to suffer from malnutrition. This issue is not solely attributed to insufficient food production or poor distribution but also to economic inequalities that leave many without the financial resources to access adequate, nutritious food [8]. Moreover, just increasing food supply does not ensure food security. Food security is intricately linked to sustainability, equity, and broader socio-economic factors, including human livelihoods and animal welfare [5]. It involves not only providing adequate quantities of food but also ensuring appropriate quality to meet nutritional needs and support well-being through sustainable means, whether from domestic production or imports [3].

Globally, livestock contributes about 16% of dietary energy, which is much less than cereals (50%) and other crops (34%) [5,9]. However, the importance of livestock in improving food systems is growing, particularly through productivity increases driven by livestock intensification. This growth has been supported by advancements in feeding systems, genetics, and animal health. Since the 1960s, breeding programs to improve genetic potential, better herd management, the increased use of protein- and energy-rich feed, and a shift away from low-productivity grassland systems have improved livestock productivity [10]. As a result, feed conversion efficiency, per-animal yields, and labor productivity have improved, while greenhouse gas (GHG) emissions per kilogram of animal product have decreased [11]. In addition, sustainable pasture management practices, like integrating pasture legumes, applying beneficial soil amendments, and practicing proper grazing management (such as rotational grazing), are essential for improving both the quality and quantity of forage for livestock production [12]. Well-managed pastures have been shown to help restore the sustainable balance of crop–livestock and food systems [13]. Oldeman [14] reported that improved grazing management could lead to increased pasture production and more efficient use of resources, the rehabilitation of degraded grazing lands, and improved food production and profitability.

Pastures play a crucial role in global food security, particularly through their contributions to the production of dairy and meat from ruminant animals such as cattle, buffaloes, sheep, and goats. These livestock products constitute a significant component of the global food supply, with meat from ruminants comprising nearly 29% of total global meat consumption [15]. To enhance food security, integrating livestock and pasture management for sustainable food systems is essential. This integration involves optimizing grazing conditions, such as maintaining appropriate sward heights, which can lead to improved livestock performance through increased weight gains and enhanced carcass traits [16]. Additionally, balancing the supplementation of concentrates with pasture-based feeding systems is necessary to achieve higher overall weight gains during the grazing season [17–19].

However, as these agricultural systems evolve to meet increasing global food demands and adapt to climate change, it becomes critical to recognize the need for further development of mixed crop–livestock systems. Thornton [20] emphasizes that these integrated systems must adapt to the challenges posed by climate variability in order to continue providing sustainable and resilient food production. However, there is a lack of comprehensive literature that explores the integrated role of pastures and livestock in addressing food security through sustainable and climate-resilient management strategies. Existing studies often focus on either livestock intensification or pasture management in isolation, rather than examining their combined impact on food systems, and ecological sustainability. This fragmented approach limits a holistic understanding of how pastures and livestock systems can be optimized to enhance food security. While pastures remain integral to livestock production, their sustainable management and adaptation to climate change are crucial for ensuring long-term resilience. Therefore, this review aims to highlight the potential role of pastures and livestock in addressing food security, with specific objectives that include examining sustainable management practices, improving nutritional outcomes, assessing economic viability, understanding climate impacts, and identifying innovative production methods. The specific objectives are:

1. To examine how managing pastures and livestock together can create sustainable food systems;
2. To assess the economic potential of pasture-based livestock systems;
3. To understand how climate change affects pasture productivity and livestock systems;
4. To identify innovative methods that promote sustainable pasture and livestock production.

2. Integrating Livestock and Pasture Management for Sustainable Food Systems

Approximately 100 million people living in arid regions rely on grazing livestock as their primary livelihood, as limited environmental conditions make alternative agricultural activities impractical [21]. Consequently, milk and meat production in these areas heavily depends on pastures. Over the past 50 years, the intensification of pasture-based systems, through the strategic use of organic fertilizers like green manure, and feed supplements such as hay and crop residues, has significantly enhanced the efficiency and productivity of grazing systems. These advancements have provided a sustainable framework for balancing agricultural output with ecological stability [22]. The sustainability of livestock farming systems (LFS) has become a key issue in both public and scientific discourse, especially given the global challenges of climate change, population growth, and the need for high-quality agro-services to society. LFS are diverse, varying significantly in terms of resource use, production intensity, species reared, and alignment with local socio-economic and market contexts [23,24]. Pastures, which are central to many LFS, deliver a wide range of critical ecosystem services, including biodiversity conservation, erosion control, climate regulation, and food production [15,25].

Grazing pasture-based livestock production systems such as intensive short-duration rotational grazing (IRG) and high stocking-density grazing, manage about 60% of the world's pastures, emphasizing their significant role in supporting global food security [26]. These systems contribute substantially to global food production, supplying approximately 9% of the world's beef, 10 to 15% of milk production and 30% of sheep and goat meat [26,27]. Sustainable livestock management in pastures plays a pivotal role in influencing both forage quantity and quality through its impact on plant diversity, soil health, and nutrient cycling. As a result, pasture-based production systems are gaining increasing attention worldwide as vital, sustainable sources of animal-derived foods, effectively balancing ecological stewardship with the growing global demand for food. The success of these systems depends significantly on plant diversity, which is crucial for maintaining the health and functionality of soils, plants, and animals [28]. This diversity supports sustainable pasture management by allowing plants time to recover, enhancing soil health, and ensuring the long-term viability of pasture-based livestock production systems [29] (Table 1).

Table 1. Successful studies on pasture-based livestock systems and food security.

Animal	Pastures	Findings	Reference
Goat	Natural pastures	Goats contributed to food security by providing both a source of meat for household consumption and income from sales to purchase food and other necessities.	[30]
	Natural pastures	The study found that supplementing goat diets, especially during the dry season when forage is scarce, significantly improves nutrition and productivity, contributing to food security.	[31]
	Sown and natural pastures	Natural pasture produces milk richer in beneficial fatty acids, vitamins, and flavor compounds compared to cultivated pasture, especially when the grass is in an early growth stage.	[32]
Sheep	Sown and natural pastures	Sheep grazing on pastures may ingest soil-bound pollutants, leading to contamination in food products like milk, meat, and especially liver, highlighting the need for monitoring food safety in pasture-based production systems.	[33]
	Sown and Mediterranean pastures	Ewes grazing in legume-rich pastures, especially those with daisy plants (*Bellis perennis*), produced milk with higher levels of beneficial fatty acids, while the fatty acid content in milk decreased as lactation progressed, highlighting the importance of pasture composition and management in improving milk quality.	[34]
	Temperate pastures	High-quality pastures improve sheep performance and meat quality, with better nitrogen utilization and reduced acidosis when combined with concentrates or total mixed rations.	[35]
Pigs	Sown pastures	Guinea pigs offer ecological benefits for pasture management and provide an efficient, low-cost source of protein, enhancing food security and income for rural smallholders.	[36]
	Sown pastures	Silages from *Vigna unguiculata* and *Lablab purpureus* improved pig performance and offered smallholder farmers better pasture conservation and food storage options.	[37]
	Sown and natural pastures	Pasture-based pork production offers opportunities for improved animal welfare and sustainable food systems but requires proper management to balance pasture use and supplemental nutrition for pigs.	[38]
Chickens	Natural pastures	Pastured poultry production enhances soil fertility and farm diversity, contributing to more sustainable and resilient food systems.	[39]
	Sown pastures	Rotational grazing of Beijing-you chickens on chicory pasture improved meat quality, increased muscle weight, and reduced yolk cholesterol and feed conversion ratio, compared to chickens on bare land.	[40]
	Sown pastures	Consuming leguminous pasture increased beneficial omega-3 fatty acids in poultry meat, improved breast skin pigmentation, and positively affected meat quality, though it reduced carcass yield and meat pH.	[41]

Table 1. *Cont.*

Animal	Pastures	Findings	Reference
Beef	Natural pastures	Grazing intensity in natural grasslands could increase food production leading to a potential 5% rise in milk output and a 4% rise in meat production.	[42]
Dairy	Sown pastures	Including white clover in pastures with mid- and late-season ryegrass cultivars significantly increases herbage accumulation and nitrogen-use efficiency, leading to higher dairy production without needing to adjust the forage value index for cultivars.	[43]
Goat, sheep, cattle, pigs and chickens	Communal pastures	The study found that households with moderate or diverse livestock ownership experienced better food security, highlighting the need for context-specific approaches in development programs to improve food security through livestock.	[36]

Furthermore, the sustainable management of pastures is crucial for ensuring the continued production of beef and dairy to meet the demands of a growing global population over the next century. Pastures play a fundamental role in supporting global beef and dairy production, both of which are essential for food security and livelihoods [44]. Numerous studies have emphasized their significance in providing a reliable foundation for animal production systems. For example, a study by Kennedy [45] compared two feeding systems for dairy cows: indoor feeding with a total mixed ration (IF) and early grazing with a high herbage allowance (EG). The cows in the EG system produced higher milk protein concentrations and yields, while the cows in the IF system had higher milk fat concentrations and greater live weight. However, there was no difference in daily dry matter intake between the two systems. Another study by Wilkinson [46] focused on improving grazing systems for dairy cows to increase feed intake, pasture use, and milk production. A key challenge is encouraging farmers to adjust grazing management to reduce nitrogen excretion and increase milk yield. Potential improvements include more accurate diet formulations, supplementing grazed pastures, and using robotics and artificial intelligence in pasture management to better meet the animals' needs. Magona [47] explored the impact of climate change on beef production in South Africa's pasture-based systems. They found that under future climate scenarios (RCP4.5 and RCP8.5), the daily weight gain of cattle significantly dropped compared to current levels, with the average daily gain falling from 0.393 kg to 0.188 kg. They also observed that certain cattle breeds, like Bos taurus and Zebu indicine, experienced greater declines in performance, while the Sanga breed was more resilient.

In a related study, Razminowicz [48] compared beef from pasture-based and conventional systems. They found that pasture-raised beef had higher levels of beneficial n−3 fatty acids and a better fatty acid ratio than conventionally produced beef. Additionally, pasture-raised beef was just as tender, with less variation in texture. A further study by Greenwood [49] highlighted the importance of improving beef production systems globally by focusing on productivity, efficiency, and sustainability. It emphasized the need for nutritional support in pasture-based systems to improve cattle performance despite environmental challenges. The study also pointed out that digital technologies can help monitor cattle and environmental data, improving both animal welfare and productivity in beef production systems. These studies underscore the vital role of pasture-based systems, in global food security by providing essential ecosystem services and sustainably producing animal-derived foods. Therefore, farmers can adopt sustainable practices in pasture-based livestock systems by using diverse pasture mixtures, rotational grazing, and organic fertilizers, while monitoring soil health and forage quality. Embracing technology and engaging in collaborative learning can further enhance productivity and ensure food safety in these systems.

3. Economic Viability of Pasture-Based Livestock Systems

The future of agriculture, particularly livestock production, is increasingly centered on enhancing the economic viability and sustainability of livestock farming systems (LFS) to address global challenges, including climate change, population growth, and the degradation of agro-ecosystem services [22]. To boost productivity on pasture-based farms, it is crucial to implement strategies such as the application of nitrogen (N) fertilizers, which enhance forage growth and nutrient availability, sustainable rotational grazing to maintain pasture health and improve animal performance, and the use of improved breeds that are more resilient and efficient in production systems [50]. These strategies can prove profitable when the cost of increased production is lower than the price received for the products. Nevertheless, the focus must remain on well-managed pastures to ensure a balance between economic gains and ecological health in livestock production (see Figure 1) [13].

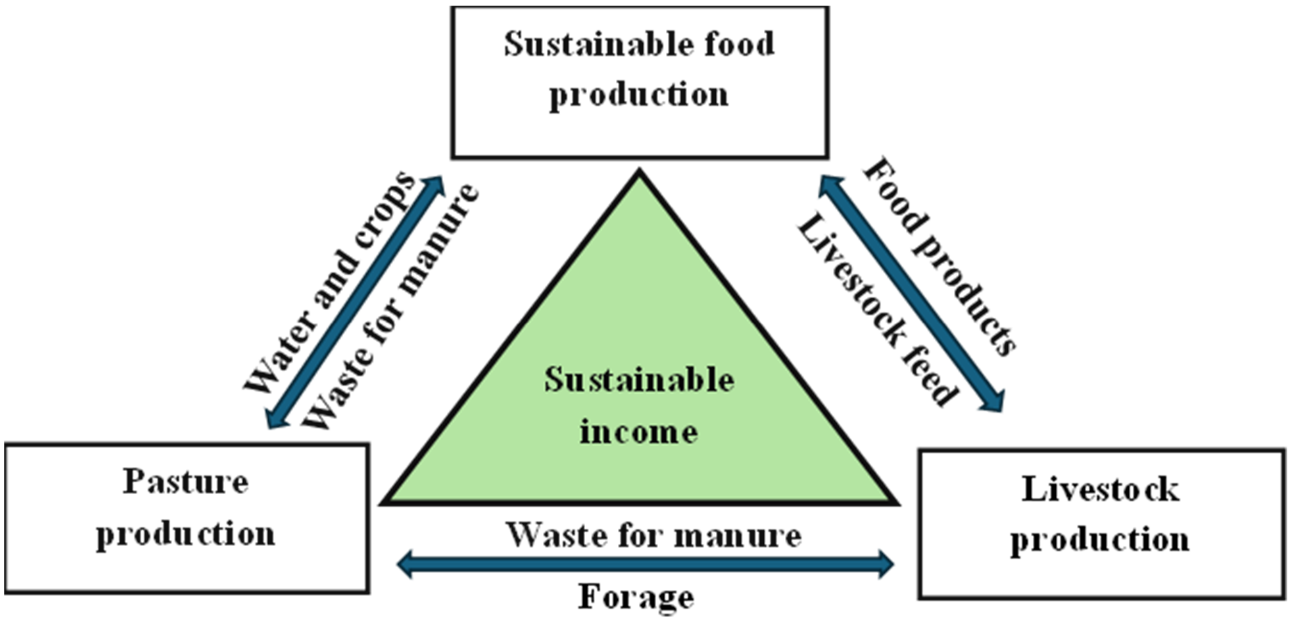

Figure 1. Integration of pasture and livestock for sustainable food security and income.

To achieve this balance, strategies such as improving livestock productivity through better feeding systems (more nutrients), animal genetics, and health, as well as practices like adding pasture legumes, improving soil health, and implementing rotational grazing, are crucial to enhancing both the quality and quantity of forage [12]. Moreover, to maintain sustainable pasture-based livestock production, grazing systems and ecological outcomes must be economically viable for land and livestock managers. The growing interest in pasture-based food production systems is driven by lower production costs, including feed, labor, and capital, and is most effective in regions with high pasture production potential, stable seasonal supply, large land availability at a low cost, and where food manufacturing is a significant part of the total production. These systems offer benefits such as improved sustainability, product quality, animal welfare, and labor efficiency [51]. Research shows that ecologically sustainable practices, such as improving soil health, implementing sustainable rotational grazing, and enhancing animal genetics and health, not only improve the environmental sustainability of pastures but also enhance the economics of livestock production (Table 2).

Table 2. Economic outcomes of pasture-based livestock systems in different countries.

Practice	Outcomes	Country	Cite
Application of Nitrogen fertilizers	Using nitrogen fertilizer to increase pasture production can yield an additional 12.2 kg of milk per kilogram of nitrogen applied, resulting in a marginal cost of about NZD 0.22 per kilogram of milk produced, which is significantly lower than the average milk price of NZD 0.45/kg.	New Zealand	[50]
Inclusion of different pastures for feed of different cattle breeds	Adding white clover to perennial ryegrass swards increased profitability by EUR 305 per hectare, with Jersey × Holstein-Friesian cows being the most profitable at EUR 2606 per hectare, followed by the 3-way cross at EUR 2492 and Holstein-Friesian at EUR 2468. The highest net profit was achieved with Jersey × Holstein-Friesian cows grazing on white clover swards, totaling EUR 2751 per hectare.	Ireland	[52]
Rotational grazing	Pasture-based cattle systems achieved a gross output of EUR 97.3 per hectare, which was higher compared to EUR 94.3 for systems with 0.25 concentration supplementation and EUR 115.3 for 0.50 concentration supplementation. The net margin for grass-only systems (G-0) was EUR 13.7, while the indoor ad libitum concentrate system (ALC) had a considerably lower net margin of EUR 1.5.	Ireland	[53]
Different grazing systems	The economic analysis revealed that the sustainable livestock grazing (SLG) system achieved a net profit of ZAR 1994.90 per hectare after one year and ZAR 2066.50 after two years, significantly higher than the four-camp grazing (FCG) and holistic planned grazing (HPG) systems. Despite increased costs associated with SLG, it generated a gross income of ZAR 2738.63 per hectare per year, compared to ZAR 508.45 for FCG and ZAR 644.82 for HPG.	South Africa	[54]
Mixed pasture species and application of inorganic fertilizers	The average gross margin from pasture-based livestock farming at the North Wyke Farm Platform (NWFP) was GBP 1178 per hectare, significantly higher than the regional average of GBP 786 per hectare.	UK	[55]
High utilization grazing	Pasture-based beef farms in the Alentejo region averaged an operational output of EUR 3 per hectare, with animal production accounting for 87% of the total farm output, averaging EUR 137,788 per farm. The top-performing farms achieved operational outputs of EUR 81 per hectare and an average carbon footprint of 20.2 kg CO_2 per kg of live weight produced, showcasing the potential for profitability and environmental sustainability in pasture management.	Portugal	[56]

Furthermore, Muñoz-Ulecia [19] showed that relying more on self-produced feeds and natural grazing improved the sustainability of mountain pasture systems. Similarly, Kumm and Hessle [57] discovered that organic beef farming on abandoned or marginal lands in Sweden was more profitable than forestry, especially with herds of over 20 cows. In the U.S., Ge [58] found that grass-fed beef could compete with grain-fed beef if economies of scale were achieved, and high-quality pasture was available. Ashfield [59] emphasized that maximizing grass in the diet and achieving good weight gain from grazing were key to profitability in beef production. Pasture systems are also beneficial for other livestock. Sossidou [39] found that pastured–poultry systems improved pasture fertility and farm diversity. However, they also highlighted challenges such as higher mortality rates, health issues, and economic inefficiencies in small-scale systems. For pigs, Northeast [60] found that pasture-raised pork had strong market demand and boosted local economies. Maass [61] showed that including energy-rich forages in pig diets reduced feed costs and improved profitability for smallholder farmers in Uganda.

In sheep farming, Chetroiu [62] demonstrated that alternative fodder (*Pennisetum glaucum* and *sorghum*) could improve profitability in lowland farms of all sizes. Fetherstone [63] highlighted the role of genetics, showing that high maternal genetic merit animals increased profits, while sheep farming systems in New Zealand had the highest overall profitability. In Brazil, Lôbo [64] emphasized the importance of traits like carcass yield and lambing percentage, showing how small improvements could significantly boost profits. In pasture-based systems for Rayeni Cashmere goats, Borzi [65] found that traits such as kid weight and cashmere yield were the most profitable, recommending selection strategies focused on body weight, milk yield, and cashmere weight to maximize economic gains. Similarly, Alexandre [66] evaluated carcass yield and quality in Creole male goats under pasture-fed (PF) and indoor-fed (IF) systems, finding that indoor-fed goats had higher fat deposition (+60% omental fat, +18% shoulder fat) and better meat color scores (+24%) compared to pasture-fed goats. Extending fattening duration in these systems increased slaughter weight by 40% and carcass weight by 60%, resulting in lean carcasses with a 53% yield and a fat score of 2/5, highlighting the potential for niche markets focused on lean meat. These studies demonstrate that pasture-based systems can be profitable and sustainable when supported by the right management practices, resources, and breeding strategies.

4. Climate Change and Its Impact on Pasture Productivity and Livestock Systems

Climate change is significantly affecting pasture productivity and quality, with rising temperatures and shifting precipitation patterns altering forage nutritional value [67]. Warmer and drier conditions are reducing pasture protein content and digestibility, which can have serious economic consequences for livestock-based economies [68]. While increased temperatures may enhance photosynthesis and plant biomass, they often lower digestibility by accelerating fiber accumulation [69–71]. Drought can further limit plant growth, though moderate water shortages may improve forage quality by reducing tissue hardening [68,71,72]. These climatic stressors affect key plant processes such as protein stability, membrane fluidity, nitrogen metabolism, oxidative stress, and photosynthesis [73,74]. These shifts in pasture conditions are largely driven by rising atmospheric carbon dioxide (CO_2) levels, which alter plant composition and growth patterns. As climate patterns become more unpredictable, the carrying capacity of pastures is declining, threatening grazing ecosystems and the livelihoods of millions [75]. Extreme weather events including heatwaves, droughts, and floods pose additional risks, particularly in arid and semi-arid regions [76]. Beyond its impact on forage availability and quality, climate change is also affecting livestock production [77]. While global demand for livestock is rising, increasing production without exacerbating greenhouse gas emissions remains a challenge [78,79]. The impacts of climate change on livestock are both direct and indirect (Figure 2). Direct effects stem from rising temperatures, which challenge livestock thermoregulation, metabolism, immune function, and overall productivity, leading to greater risks of heat stress, illness, and even mortality [77,79–82]. Indirect effects result from changes in forage and feed production, water scarcity, and the spread of pests, pathogens, and diseases such as vector-borne and food-borne illnesses that further reduce livestock productivity [82,83]. The long-term implications of climate change on pasture-based systems and livestock production remain uncertain. Understanding how temperature and rainfall fluctuations affect forage production, nutritional value, and livestock resilience is critical for developing sustainable grazing strategies in a changing climate [84,85].

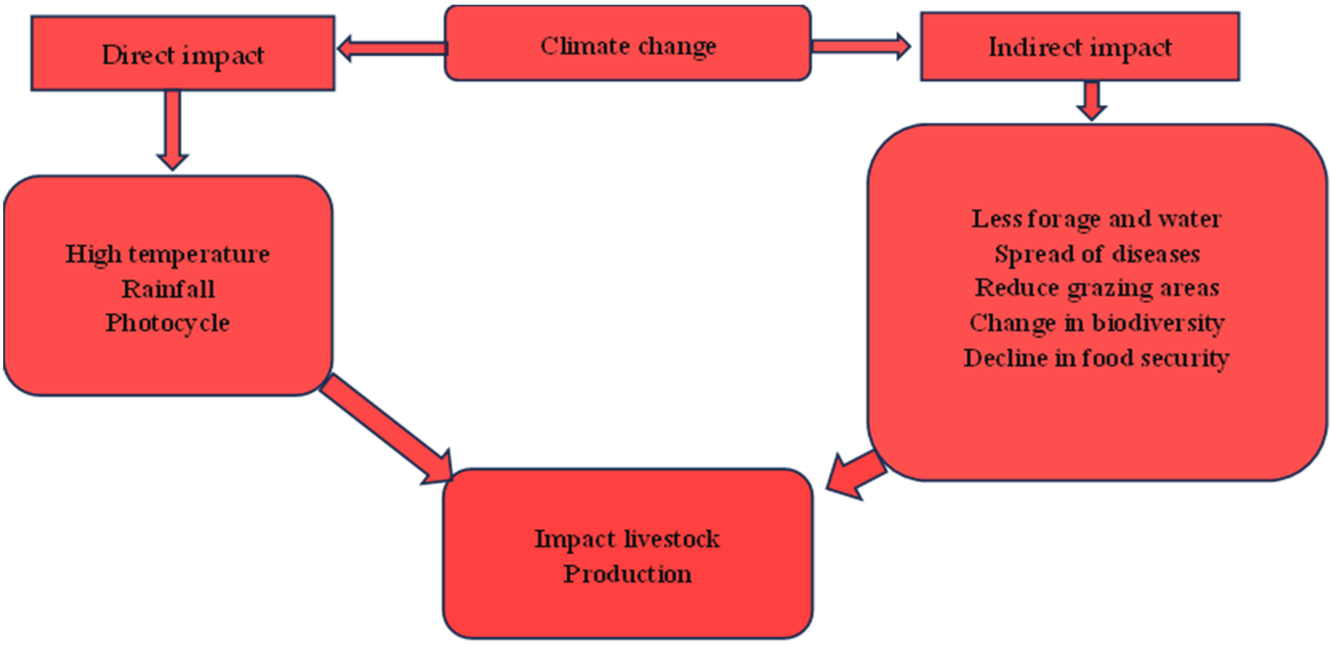

Figure 2. Effects of climate change on livestock production. Adopted from Sejian [78] and Behera [79].

Several studies have shown that climate change negatively affects livestock production in different ways. For example, Cheng [74] discusses how climate change impacts livestock growth, production, and health, while also contributing to emissions. They suggest that adaptation and mitigation measures can help reduce these effects and maintain livestock production. They also stress the need for more research in developing countries to find effective strategies for adapting to and mitigating these impacts. Similarly, Godde [86] highlights that climate change will affect the entire livestock supply chain, from production to consumption. However, quantifying the full impact is challenging. The risks are especially high in hot regions, where resources for adaptation are limited. Therefore, they suggest that adaptation strategies should consider a range of possible future climate scenarios, including those that are less likely but could have serious consequences.

In addition, Gaughan and Cawdell-Smith [81] highlight that climate change is expected to negatively affect livestock performance, particularly in developing countries where livestock production is primarily based on natural grazing systems. In these regions, most livestock producers are smallholder farmers who depend heavily on natural systems for their food and income. Livestock under these systems often struggle to adapt to climate stress due to poor physiology and genetics, leading to production losses and increased costs. Given these challenges, it is recommended that the focus should shift toward improving management practices to help livestock systems adapt to climate change in a sustainable manner. Lastly, Ali [82] reports that in Bangladesh rising temperatures and extreme weather events are causing heat stress, metabolic disorders, and higher risks of disease in livestock. The livestock sector, which is crucial for food security and the economy, is vulnerable to these impacts. However, together, these studies emphasize the need to understand and address the impacts of climate change on livestock. This is crucial for ensuring food security and maintaining sustainable agricultural systems, particularly in regions that are vulnerable to climate extremes. By focusing on adaptation and mitigation strategies, such as improved management practices and climate-resilient breeds, we can help livestock systems cope with the changing climate and minimize the negative effects on production, health, and overall food security.

5. Innovative Practices for Sustainable Pasture and Livestock Production

Sustainably intensifying grazing-based animal production systems is crucial for both protecting ecosystems and meeting the growing demand for protein. To achieve this, several approaches are available including diversifying plant and animal species, improving grazing management and feeding techniques, breeding plants for better nutrient use, and integrating crop–livestock or silvo-pasture systems [83]. For these systems to be successful, it is important to adopt new practices and technologies. These include genetic improvements in cattle or forages, or a combination of new and existing management practices. However, these changes require livestock producers to adopt new behaviors [83,84]. Identifying best management practices that maximize ecosystem services while ensuring farm profitability is key to providing both economically and environmentally sustainable protection for endangered ecosystems [84].

One example is management-intensive rotational grazing, where animals graze for short periods, followed by longer rest periods for the land. This practice helps maintain healthy pastures and increases the land's ability to support more livestock [85]. Wang [87] found that SRT increased forage yields by 20.8% and improved farmers' income by 17%, making it a practical solution for semiarid regions. Other sustainable approaches, such as agroecology and agroforestry, utilize methods like no-till farming and cover crops to support natural processes within agricultural systems. These practices not only enhance productivity but also improve soil health, increase resilience to climate change, and provide valuable ecosystem services [88,89]. Recognized as some of the most holistic and effective solutions to the challenges facing the agri-food system, agroecology and agroforestry can be integrated across multiple scales to optimize both environmental and economic benefits [90,91]. As regenerative approaches, they sustain long-term productivity while simultaneously delivering essential ecosystem services through nature-inspired methods [92,93].

Technological advancements, such as remote sensing and machine learning, are increasingly used to monitor and quantify pastures. For example, Ramoelo and Cho [94] demonstrated that leaf nitrogen (N) levels can be monitored using high-resolution satellite images, with the red-edge band being particularly effective. This is valuable for assessing the quality of rangeland forage. Pringle [95] used satellite data to predict changes in forage quality as the seasons changed in northeast Australia's dry savannas, showing that their model could accurately forecast dietary crude protein and dry-matter digestibility with minimal error. In another study, Rapiya [96] used Sentinel-1 and Sentinel-2 satellite data to estimate and map nutrient levels (nitrogen, phosphorus, and neutral detergent fiber) in mesic tropical rangelands. The study found that this approach provided highly accurate predictions and monitoring of features of pastures, with factors such as season and slope significantly influencing nutrient distribution. Similarly, Akumu [97] used high-resolution drone and satellite data to monitor grazing land before and after flooding. Their findings showed a 7% increase in pasture cover and a doubling of pasture quality after the floods. Similarly, a study in England and Wales by Lima [98] focused on the adoption of electronic identification (EID) technology among sheep farmers. The study found that adopters of EID viewed it as practical and beneficial, while non-adopters felt pressured by the government. Flocks using EID showed fewer cases of lameness, and farmers with higher IT literacy and plans for intensifying production were more likely to adopt the technology. In line with these findings, Fariña [99] also highlights the importance of tailored technology transfer, innovation programs, and policies to enhance milk production while considering economic, social, and environmental impacts. Together, these innovative approaches demonstrate how technology can play a key role in restoring and managing pastures by improving both animal health and production efficiency.

Furthermore, sustainable practices in animal production, through proper resource management, play a crucial role in protecting the environment while enhancing the cost-effectiveness of farming, thereby ensuring long-term sustainability [100–102]. Various regions have adopted different approaches to achieve sustainable livestock production. For instance, a study in the USA by Gwin [103] explored the challenges faced by grass-fed beef producers, including issues related to on-farm inputs, processing, marketing, and finance. While entrepreneurial innovations offer some solutions, the study suggests that broader systemic approaches are needed to support the sector's growth. It also points out that scaling up operations must be balanced with potential environmental and social impacts. In Uruguay, Ruggia [104] investigated how ecological intensification can improve the sustainability of family-run livestock farms on native grasslands. Over three years, this approach led to better economic outcomes (higher gross margins, better return to labor, and increased family income), improved social aspects (reduced workload), and positive environmental impacts (maintained or increased bird diversity and ecosystem integrity). This suggests that ecological practices can enhance productivity, biodiversity, and resilience in livestock farming.

In Africa, Gilbert [105] examined the environmental, health, and social impacts of both extensive and intensive livestock production systems, focusing on chicken and pig farming. They developed a model that links the proportion of extensively raised animals to a country's GDP per capita, helping to distinguish between the two production systems globally. The findings highlighted key regions where each system is most prominent and discussed potential future trends in intensifying livestock production. Lastly, in Asia, Hayakawa [106] studied the economic benefits and ecological sustainability of integrated crop–animal systems, which combine ruminants and non-ruminants with crops. The study emphasized the need for research on feed resources, indigenous animal genetics, and disease management to improve livestock production. It also stressed the importance of enabling policies and increased investment to promote sustainable livestock farming and natural resource management in tropical regions. Collectively, these studies show that sustainable livestock production requires diverse strategies tailored to regional contexts, balancing economic, social, and environmental factors to ensure long-term sustainability.

6. Reflections on Sustainable Food Systems Through Livestock and Pasture Management

The integration of pasture and livestock management represents a fundamental strategy to address the multifaceted challenges of global food security in the context of a rapidly growing population and climate change. Sustainable livestock production is not merely about increasing outputs; it requires a holistic approach that harmonizes agricultural practices with ecological stewardship. This includes recognizing the critical role of well-managed pastures, which can restore degraded lands, enhance soil health, and improve animal welfare. Considering growing consumer demand for diverse diets rich in meat and dairy, innovative practices such as rotational grazing, agroecology, and the application of technology in pasture management emerge as vital. By facilitating resilient and efficient grazing systems, these methods promise to sustainably balance ecological integrity with agricultural productivity, ensuring a reliable supply of animal-derived foods.

Moreover, as the world grapples with the realities of climate change, adaptation strategies will be essential to safeguard livestock systems against environmental stresses. This necessitates a proactive mindset among stakeholders, encompassing farmers, researchers, and policymakers, to collaboratively explore sustainable practices and develop context-specific adaptations. Investing in innovative technologies that monitor pasture quality, enhance animal genetics, and promote farmer education in sustainable practices will be essential components of this transition. Ultimately, realizing the potential of pasture-based livestock systems to contribute to food security is a shared responsibility that demands interdisciplinary collaboration across scientific research, agricultural policy, and community engagement. Together, we can pave the way for resilient food systems that not only meet the needs of future generations but also support the health of our ecosystems.

7. Conclusions

The global population, projected to reach 10.9 billion by 2100, poses significant challenges to food security, particularly due to rising demand for protein-rich foods like meat and dairy. Meeting this demand requires a 25–70% increase in agricultural yields while ensuring equitable access to nutritious food. Pastures and livestock are crucial to sustainable food systems, contributing significantly to global milk and meat supplies. Effective pasture management, including rotational grazing and biodiversity enhancement, improves livestock productivity while restoring soil health and ecosystem integrity. Climate change presents a major threat to pasture productivity and livestock health, with erratic weather patterns and extreme events exacerbating food security concerns for vulnerable communities reliant on livestock. Adaptive strategies, such as management-intensive rotational grazing and digital monitoring technologies, offer promising solutions. Policymakers and extension services must prioritize sustainable pasture and livestock management through targeted initiatives. Developing policies that support sustainable agriculture, incentivizing environmentally friendly practices, and implementing capacity-building programs on pasture and livestock management are critical. Investments in research and development should focus on improving pasture productivity and livestock resilience in the face of climate change. Providing smallholder farmers with access to quality seeds, organic fertilizers, and veterinary services will enhance the adoption of sustainable practices. Collaboration among governmental agencies, NGOs, and local communities can create a supportive environment for sustainable agriculture. Future research should emphasize adaptive strategies such as drought-resistant forage varieties, integrated pest management, and precision agriculture for optimizing resource use. Expanding consumer awareness of sustainably produced livestock products and fostering international cooperation for knowledge exchange will further enhance food security. By integrating these strategies, stakeholders can promote resilient pasture-based livestock systems that support long-term food security and environmental sustainability.

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