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# Addressing low livestock production: Key factors, challenges, and sustainable solutions for improved agricultural output, A review

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## Abstract

**Introduction/Background:** Livestock manufacturing plays a critical role in worldwide food security and rural livelihoods, yet many regions face persistent challenges of low productivity. This complete evaluation examines the important thing elements contributing to low livestock production, the challenges faced by way of farmers and policymakers, and sustainable answers for improving agricultural output. The livestock zone, encompassing livestock, poultry, small ruminants, and different animals, is a crucial factor of agriculture, offering crucial proteins, profits, and various environmental services. However, numerous factors, including restricted entry to assets, insufficient animal health offerings, and environmental constraints, avert ideal manufacturing tiers in many components of the sector.

**Materials and Methods:** This overview synthesizes findings from an extensive variety of peer-reviewed articles, research reviews, and coverage documents that specialize in farm animal manufacturing structures, challenges, and interventions. The method entails a systematic analysis of literature, encompassing both advanced and developing United States contexts. Special interest is given to studies addressing included crop-cattle systems, network-based totally animal fitness approaches, and modern strategies for sustainable intensification.

**Results:** The overview identifies several key elements contributing to low farm animal production, inclusive of restrained access to first-rate feed and water, the prevalence of animal illnesses, inadequate breeding applications, and negative market access. Climate trade emerges as a large undertaking, exacerbating existing constraints and introducing new dangers to livestock structures. The analysis reveals that successful interventions regularly contain a mixture of technological improvements, coverage reforms, and network-based totally methods. Integrated crop-cattle systems show promise in improving typical farm productiveness and resilience.

**Discussion:** The findings highlight the complex interplay of factors affecting farm animal manufacturing and the want for context-specific solutions. While technological innovations provide sizeable potential for improvement, their effectiveness relies upon addressing broader socio-monetary and institutional constraints. The evaluation underscores the significance of participatory techniques and the integration of traditional knowledge in growing sustainable livestock production strategies.

**Conclusion:** Addressing low farm animal production requires a multifaceted approach that combines improved animal genetics, higher fitness offerings, sustainable feed solutions, and allowing guidelines. The review concludes that improving farm animals' productiveness is not simplest vital for meal security but also offers opportunities for poverty discounts and environmental sustainability. Future research and development efforts should focus on scalable, incorporated solutions that could adapt to various Agroecological and socio-economic contexts.

**Keywords:** Livestock Production; Integrated Farming Systems; Sustainability; Climate Change; Animal Health; Genetic Resources; Nutrient Recycling; Food Security; Biodiversity; Agroecology; Greenhouse Gas Emissions

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## 1. Introduction

Livestock production paperwork is a cornerstone of world agriculture, gambling a pivotal role in food safety, rural livelihoods, and monetary development. According to the Food and Agriculture Organization (FAO, 2015), the farm animal sector contributes extensively to agricultural GDP in many nations, offering critical proteins, profits, and numerous atmosphere services. However, regardless of its significance, many regions around the sector grapple with chronic challenges of low livestock productivity, hindering the world's capability to satisfy the developing demand for animal-sourced foods and help sustainable rural development. This comprehensive review pursuits to study the key elements contributing to low farm animal manufacturing, analyze the multifaceted challenges confronted by farmers and policymakers, and discover sustainable answers for enhancing agricultural output in various contexts.

The worldwide farm animals sector has gone through extensive alterations in latest a long time, pushed using populace boom, urbanization, and changing nutritional possibilities. As cited via Delgado *et al*. (2008), the speedy growth of cattle production, in particular in developing nations, has been termed the "Livestock Revolution." This phenomenon has introduced both opportunities and demanding situations, with the intensification of manufacturing structures raising concerns about environmental sustainability, animal welfare, and the livelihoods of smallholder farmers. Despite these adjustments, many areas continue to struggle with low productiveness ranges, particularly in widespread structures that dominate in marginal regions. Herrero *et al*. (2012) highlight the diverse roles of livestock in growing international locations, emphasizing their contribution to food security, earnings technology, and cultural values. Understanding the complex elements that impact farm animals' productiveness is essential for developing powerful strategies to cope with these challenges and harness the sector's capacity for sustainable development.

The demanding situations facing farm animal manufacturing are multifaceted and often interrelated, encompassing biological, environmental, socio-economic, and institutional elements. According to Thornton and Herrero (2015), climate exchange poses a widespread risk to cattle structures, particularly in prone regions including sub-Saharan Africa, wherein rising temperatures and changing precipitation styles exacerbate existing constraints on feed and water availability. Additionally, the superiority of animal illnesses remains a chief impediment to productivity, with insufficient veterinary services and restrained admission to animal fitness interventions hampering efforts to improve herd health and overall performance. Randolph *et al.* (2007) emphasize the crucial role of cattle in human vitamins and fitness, particularly in developing international locations, underscoring the importance of addressing those manufacturing constraints to gain broader development goals.

Efforts to deal with low farm animal productiveness have developed over the years, with a developing recognition of the need for integrated, sustainable methods that remember the wider agroecological and socio-economic context. Sanderson *et al*. (2013) spotlight the potential of included crop-livestock systems in North America, demonstrating how such processes can enhance aid use efficiency and farm resilience. Similarly, Wright *et al.* (2012) talk about the mixing of plants and cattle in subtropical agricultural systems as a promising approach for improving overall farm productiveness and sustainability. These incorporated approaches replicate a shift toward greater holistic, systems-based wondering in addressing agricultural challenges, recognizing the interconnections between exclusive components of farming structures and the broader panorama.

The cause of this comprehensive assessment is to synthesize present-day information on the factors contributing to low farm animal manufacturing, analyze the demanding situations faced in one-of-a-kind contexts, and discover sustainable answers for enhancing agricultural output. By examining a huge variety of literature and case studies, this assessment aims to provide a nuanced knowledge of the complicated issues surrounding livestock productiveness and provide insights into effective strategies for addressing those challenges. The thesis of this review posits that enhancing cattle manufacturing calls for a multifaceted technique that mixes technological innovations, coverage reforms, and community-based total interventions, tailored to unique agro-ecological and socio-financial contexts. Through this evaluation, the assessment seeks to contribute to the continued discourse on sustainable cattle improvement and inform destiny research and policy guidelines in this critical vicinity of agriculture.

## 2. Conceptual framework

### 2.1. Historical Context of Livestock Production

The domestication of animals for meals, fiber, and labor has been a cornerstone of human civilization for millennia, shaping agricultural practices, diets, and cultural traditions across the globe. According to Gupta (2004), the origins of agriculture and animal domestication can be traced lower back to the early Holocene length, coinciding with significant climate amelioration that allowed for the development of settled groups and greater in-depth food production structures. This long history of human-animal interaction has led to the development of diverse livestock breeds and manufacturing systems adapted to a huge range of environmental situations and cultural alternatives. The evolution of farm animal manufacturing has been carefully intertwined with broader agricultural developments, with animals playing critical roles in nutrient biking, draft strength, and threat management techniques for farmers (Wilkins, 2007). As societies have evolved, so too have cattle production systems, starting from conventional pastoralism to fashionable in-depth operations.

The 20th century saw significant alterations in cattle production, pushed by technological improvements, a population boom, and converting financial structures. The Green Revolution, which frequently targeted crop manufacturing, additionally had profound implications for cattle systems, mainly via the accelerated availability of crop residues and via merchandise as animal feed (Pinstrup-Andersen, 2007). This duration witnessed the rise of specialized, intensive farm animal manufacturing systems in many parts of the sector, characterized by way of excessive inputs of feed, advanced genetics, and advanced control practices. However, as mentioned by using CAST (1999), those traits have no longer been uniform throughout regions, with many regions, in particular inside the developing world, continuing to depend upon extra conventional, significant manufacturing structures. The coexistence of numerous production models, ranging from smallholder combined farming to huge-scale commercial operations, displays the complex panorama of global livestock manufacturing and the varying demanding situations confronted in unique contexts.

The latter part of the 20th century and the early twenty-first century have visible developing recognition of the environmental and social implications of livestock production. Concerns approximately deforestation, greenhouse gasoline emissions, and water pollution associated with in-depth cattle systems have caused increased scrutiny of the sector's sustainability (Tilman, 1999). At the same time, there has been a renewed appreciation for the multifunctional roles of livestock in rural livelihoods, in particular in developing international locations. Randolph *et al.* (2007) highlight the important contributions of cattle to human vitamins, profit generation, and social capital in resource-poor communities. This complicated interaction of ecological, monetary, and social elements has formed contemporary debates approximately the destiny of livestock production and its role in sustainable improvement.

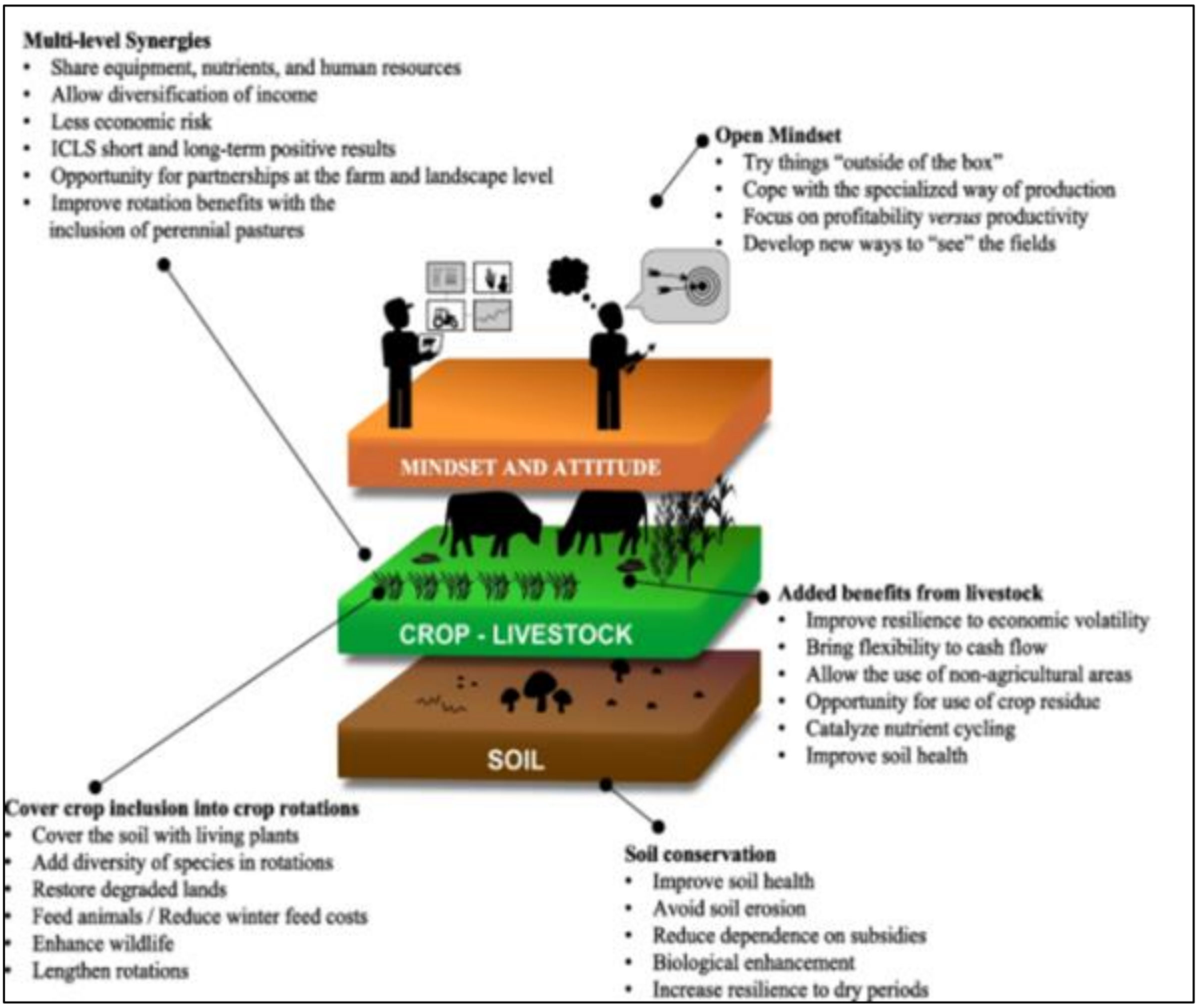
Recent years have seen a shift towards greater holistic, integrated techniques to cattle production that propose stability and productiveness with environmental sustainability and social fairness. The concept of sustainable intensification has won traction as a capability pathway for meeting growing meal demand even while minimizing environmental impacts (Garrett *et al.,* 2017). This technique emphasizes the importance of context-specific solutions that leverage neighborhood knowledge and resources at the same time as incorporating suitable technologies and control practices. Additionally, there was growing interest in the revival and variation of traditional cattle control practices, which include blended crop-cattle systems and rotational grazing, which give capability benefits for both productiveness and surrounding fitness (Sanderson *et al*., 2013). These evolving views on livestock manufacturing mirror broader shifts in agricultural questioning closer to greater sustainable, resilient, and inclusive food systems.

### 2.2. Global Importance of Livestock Production

Livestock manufacturing plays a vital function in international meal safety, monetary improvement, and cultural identification, contributing notably to the livelihoods of thousands and thousands of people globally. According to the Food and Agriculture Organization (FAO, 2015), the cattle sector debts to about 40% of the world's agricultural GDP, highlighting its monetary significance. This contribution is especially suggested in growing nations, wherein farm animals regularly serve as a form of dwelling savings and insurance in opposition to crop screw-ups or other shocks. Herrero *et al.* (2012) emphasize the multifaceted roles of cattle in growing nations, inclusive of their contributions to nutrition, profit generation, and social repute. The sector affords essential animal-sourced meals, such as meat, milk, and eggs, which are rich resources of outstanding proteins and micronutrients vital for human fitness and development.

The global call for farm animal products has been steadily increasing, driven using populace increase, urbanization, and rising incomes in lots of components of the arena. Delgado *et al.* (2008) describe this phenomenon as the "Livestock Revolution," noting the speedy growth of farm animals manufacturing, in developing countries. This trend has great implications for agricultural systems, rural economies, and worldwide alternate styles. However, the growth in call for also gives challenges, particularly in phrases of environmental sustainability and the need to ensure equitable right of entry to animal-sourced foods. The cattle region is a main person of natural resources, along with land, water, and feed vegetation, and contributes considerably to greenhouse fuel emissions (FAO, IFAD, WFP, 2018). Balancing the growing demand for livestock products with environmental sustainability and climate change mitigation dreams remains an important task for the arena.

To address those challenges, Moojen *et al.* (2021) present a comprehensive framework of producers' perceptions regarding sustainable incorporated crop-cattle systems (ICLS). Their findings, illustrated in Fig 1, highlight several key levers towards sustainability in ICLS. As shown in Fig 1, the framework emphasizes the importance of a holistic technique, integrating crop and farm animal manufacturing with soil conservation practices and an open mindset. The framework in Fig 1 outlines multi-level synergies, including sharing equipment, nutrients, and human resources, while also emphasizing the importance of an open mindset to "think outside the box" and focus on profitability versus productivity. Livestock production structures vary broadly across the globe, reflecting diverse agroecological situations, cultural preferences, and economic contexts. Extensive pastoral systems, which might be common in arid and semi-arid regions, play an essential function in using marginal lands which can be improper for crop production (Manzano, 2017). These structures are frequently well-adapted to local environmental conditions and offer livelihoods for hundreds of thousands of pastoralists. In evaluation, intensive livestock manufacturing systems, that are more not unusual in evolved countries and increasingly in emerging economies, are characterized with the aid of excessive inputs and outputs, often focusing on a single species or product. Between those extremes lie a huge variety of blended farming systems, where vegetation and cattle are incorporated to varying degrees. Wright *et al*. (2012) spotlight the capacity of incorporated crop-farm animal structures to enhance ordinary farm productivity and resilience, particularly in subtropical areas.




Source: Moojen *et al.,* (2021).

**Figure 1** Producers' perceptions of levers towards sustainable integrated crop-livestock systems (ICLS)

Building on this, Moojen *et al.* (2021) identify several multi-level synergies in ICLS, as depicted in Fig 1, consisting of the sharing of system, nutrients, and human resources, diversification of income, decreased financial chance, and stepped forward rotation benefits via the inclusion of perennial pastures. These synergies contribute to both short-term and long-term positive results and create opportunities for partnerships at the farm and panorama degree. The farm animals quarter also performs a great position in worldwide environmental and weather alternate dynamics. While livestock production contributes to greenhouse gas emissions, in most cases through enteric fermentation and manure control, it additionally has the potential to make contributions to weather trade mitigation and model strategies. Godber and Wall (2014) discuss the vulnerability of farm animal systems to climate change and populace increase, emphasizing the need for adaptive techniques to ensure food security. Sustainable cattle management practices, consisting of stepped forward grazing systems and manure management, can contribute to carbon sequestration and soil health improvement.

Moojen *et al.* (2021) further emphasize the importance of soil conservation in ICLS, highlighting practices including enhancing soil health, warding off soil erosion, decreasing dependence on subsidies, enhancing biological activity, and increasing resilience to dry durations. They also strain the added benefits of cattle in these structures, which include progressed resilience to financial volatility, multiplied flexibility in coins go with the flow, usage of non-agricultural regions, and catalysing nutrient biking. Furthermore, cattle play an important position in nutrient biking and retaining biodiversity in lots of ecosystems. Recognizing and improving those wonderful environmental contributions of farm animal manufacturing is increasingly seen as a key aspect of sustainable agricultural improvement. Moojen *et al*. (2021) advocate that this may be done via an open mindset that encourages producers to suppose "outdoor the box," address specialized approaches of manufacturing, cognizance of profitability as opposed to productiveness, and increase new approaches to "see" the fields.

### 2.3. Key Challenges in Livestock Production

Livestock manufacturing faces numerous demanding situations that avert its capacity to satisfy worldwide meal demand sustainably and help rural livelihoods efficaciously. One of the primary challenges is the restricted access to nice feed and water sources, mainly in regions at risk of drought and weather variability. According to Alders, (2012), feed shortage is a primary constraint to farm animals' productiveness in many components of Africa, with seasonal fluctuations in feed availability leading to negative animal overall performance and multiplied vulnerability to sicknesses. This challenge is exacerbated with the aid of climate trade, which is changing precipitation patterns and growing the frequency of severe climate activities. Thornton and Herrero (2015) highlight the need for adaptive strategies to beautify the resilience of livestock structures in the face of weather alternatives, together with the improvement of drought-resistant forages and progressed water management practices.

Animal fitness troubles pose any other considerable project to farm animal production, with diseases inflicting huge economic losses and impacting animal welfare. The incidence of each endemic and emerging disease varies throughout regions, with growing countries often going through more challenges due to confined veterinary infrastructure and resources. Leyland *et al.* (2014) talk about the significance of network-based totally animal medical experts in addressing these challenges, mainly in far-off and underserved areas. The unfolding of zoonotic diseases additionally represents a growing challenge, highlighting the interconnections between animal health, human health, and environmental factors. Addressing these fitness challenges calls for a complete technique that mixes progressed ailment surveillance, vaccination packages, and ability building in veterinary services.

Genetic development of farm animal breeds is important for reinforcing productiveness, but many smallholder farmers have been restricted get admission to progressed breeding stock and artificial insemination offerings. Ahuja *et al*. (2008) describe the fulfillment of the Kur Oiler poultry breed in West Bengal, India, for instance of ways progressed genetics can notably increase productiveness in smallholder systems. However, scaling up such interventions and ensuring their sustainability remains a task in many contexts. Additionally, there's a need to balance genetic improvement for productiveness with the conservation of nearby breeds which can be properly tailored to particular environmental situations and own treasured trends including disorder resistance (FAO, 2015). This stability is specifically important in the context of weather alternate, in which resilience and flexibility are becoming increasingly essential developments.

Market access and value chain improvement represent every other set of demanding situations for cattle manufacturers, in particular smallholders in faraway areas. Limited infrastructure, excessive transaction fees, and the absence of marketplace records often save you, farmers, from absolutely profiting from their cattle production. Ponnusamy and Devi (2017) emphasize the importance of incorporating farming device approaches in enhancing farmers' earnings, highlighting the want for holistic interventions that deal with each manufacturing and marketplace-associated constraints. Developing efficient and inclusive value chains for livestock merchandise calls for coordinated efforts among multiple stakeholders, consisting of producers, processors, traders, and policymakers. Addressing these market-associated challenges is vital for incentivizing investments in farm animals' productiveness and making sure that enhancements in production translate into tangible benefits for farmers, (Veysset *et al.,* 2014).

## 3. Methodology

The technique for this examination concerned a complete and systematic method to amassing, reading, and synthesizing applicable literature on livestock manufacturing, challenges, and sustainable solutions. A wide variety of academic databases and medical repositories have been utilized to ensure a radical coverage of the situation count number. The number one resources included peer-reviewed journals, studies reports, policy documents, and publications from global businesses specializing in agriculture and livestock production.

Literature seeking and choice criteria were cautiously defined to attention on courses addressing key factors of livestock manufacturing, including but not constrained to productiveness factors, environmental impacts, socio-economic concerns, and revolutionary management practices. The seek encompassed a time-frame from 2000 to 2024, taking into account the inclusion of both seminal works and the maximum current trends inside the area. Keywords used in the seek manner included "livestock production," "animal husbandry," "sustainable agriculture," "incorporated farming systems," "animal health," and "agricultural productivity."

To maintain fairness and coverage, this review also encompassed the analysis of studies conducted in both advanced and emerging economies owing to the variation in situations. A special emphasis was on the literature on the smallholder farming systems since these systems contribute considerably to the production of livestock in the world particularly in the developing nations (Herrero *et al.* 2012). The filtering system was applied to priority to empirical, systematic, and meta-analysis studies that bear overwhelming cattle production evidence and insights.

Implementing integrated crop-livestock systems analysis was one of the activities undertaken in this research and several examples such as Lemaire *et al*, 2014 were reviewed to assess the potential of crop-livestock integration. These provided useful experience on integrated farming systems in terms of efficiency, sustainability, and resilience in agroecological zones.

In dealing with productivity as affected by the deficiency of animal health, provision came for review of literature on community animal health approaches as researched by Leyland *et al*. (2014). This facet of the review sought to look into the usefulness of such people-driven participation in deploying grassroots-based animal health services in neglected zones.

How livestock production affects the environment and what studies have investigated the contribution of this sector to climate change and its responses were also topics of review in the literature. The studies carried out by Thornton & Herrero (2015) and Godber & Wall (2014) have contributed significantly to comprehending the interplay between livestock systems and climate change and food security and food systems.

On the socio-economic dimension of livestock production, the methodology entailed analysis of other papers that addressed how livestock played diverse roles in the livelihoods of rural households. As will be seen from the work of Randolph *et al*. (2007), there was useful information about the contribution of livestock in supporting human nutrition and reducing poverty in the developing world.

Technological advancements, in addition to their capabilities in enhancing productivity in the livestock sector, were also reviewed during the assessment, (Tarawali, 2018). This included an assessment of precision livestock farming, genomic breeding, and new feed management strategies. Concerns related to the potential of these technologies to increase productivity with consideration of environmental impact were of prime interest in this aspect of the review.

Thus, as part of the methodology, separate reports and data obtained from international organizations, including the Food and Agriculture Organization (FAO), were reviewed. FAO reports on "The State of Food and Agriculture" of the year 2009 and "The State of the World's Animal Genetic Resources for Food & Agriculture" of the year 2015 helped in offering background information and statistics on the Global livestock farming industry and its issues.

The review process also looked into examples of successful intervention and more importantly new paradigms in the rearing of livestock. This involved assessments of, for example, the Kuroiler poultry breed in West Bengal, India (Ahuja *et al.,* 2008), to illustrate the possibility of improvements in genetics about smallholder livestock-keeping systems.

Due to the increasing relevance of sustainable intensification in animal farming, the methodology also involved the analysis of literature on productivity increase and improved environmental management. Applicable literature from Garrett *et al*. (2017) and Sanderson *et al.* (2013) looked into the viability of sustainable intensification strategies depending on the culture of agriculture.

Possible sources included in the analysis of market access and value chain development in the livestock sector included Ponnusamy and Devi (2017) who stressed the need for integrated interventions to increase farmer earnings as well as market linkages.

In the course of the work carried out during the literature review, efforts were made to ascertain which issues are poorly researched at the moment. This included an evaluation of the methods, coverage, and gaps within the identified research works to point out areas in which further research would enhance cumulative knowledge of the issues affecting livestock production as well as potential remedies, (Russelle *et al*., 2007).

Using the composite of literature from this broad field, the objective of this paper was to establish a detailed analysis of the various factors, that seem to affect the productivity of livestock, the difficulties, which are faced by producers in various environments, together with the possibility of utilizing different strategies to manage these difficulties sustainably. In this sense, the methodology aimed at the combination of different kinds of approaches and views to provide a comprehensive understanding of the current situation and perspective of the livestock sector, (Raney, 2010).

## 4. Literature findings

### 4.1. Integrated Farming System, Its Needs, and Components

One approach is the integrated farming system (IFS) presented in Figure 1 which shows a complex set of interrelated factors that make up a holistic model of sustainable agriculture. At the core of this system are three primary sectors: Forestry, Agriculture, and Horticulture, as clearly illustrated in Fig 2. These are supported by numerous specialized activities that form closed and mutually complementary farming systems, with Fig 2 showing components such as fish farming, apiary, dairy, and various types of animal rearing. The addition of forestry to IFS supports the results of Mbow *et al*. (2014), where they illustrated that traditional agroforestry practices can sequester a lot of carbon, at a rate of 0.5-3.0 Mg C ha−1 year−1. It is thus clear that while the integration of trees with agriculture practices helps reduce climate change, it also promotes biological diversity while adding extra sources of revenue from timber and NTFPs.

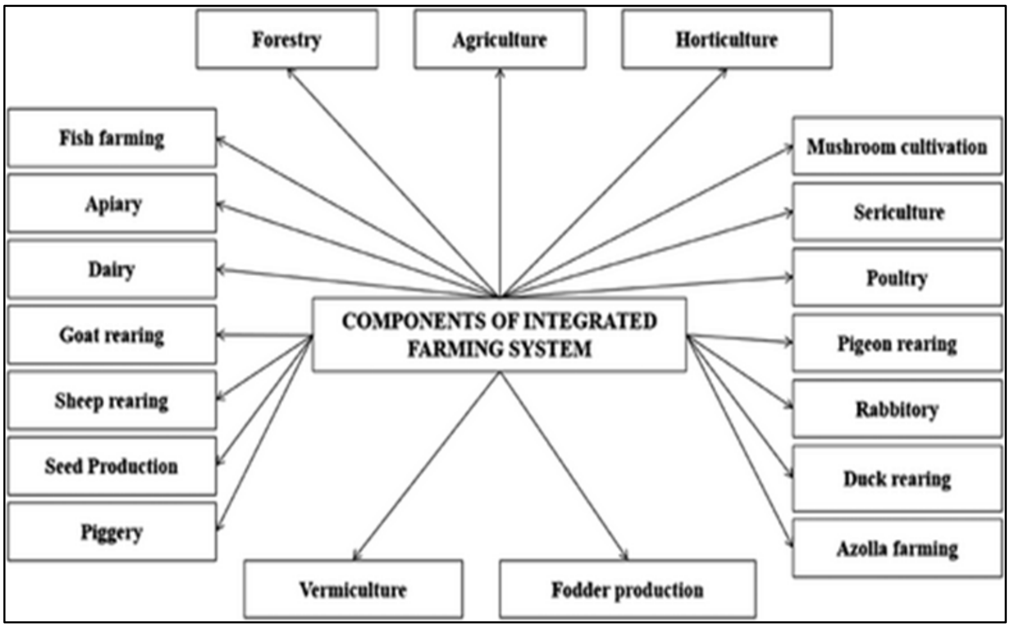



**Figure 2** Different agricultural and allied enterprises as components for IFS

Agriculturally, the food production factor includes agronomic commodities and traditional-scale farming. As depicted in Fig 2 and expanded upon in Table 1, the IFS approach broadens the meaning of farming to cover segments such as mushrooms, sericulture, and azolla, while also encompassing key components like cereals, pulses, and oilseeds for food security and income generation. All these diversified agricultural activities enhance resource productivity as well as income variation. For example, mushroom production can adopt residue from crops and this falls under nutrient recycling as highlighted by Petersen *et al* in 2007. Sericulture is the rearing of silkworms to produce silk which is another valuable crop that has a high potential to increase farm income as well as it is good for biodiversity. Azolla farming, a socio-agro technique of cultivating aquatic ferns, stands out most particularly for its nitrogen-fixing potential, which conforms to Lemaire *et al*., (2014) observation on biological nitrogen fixation in integrated systems.

**Table 1** Key Components of Integrated Farming Systems

| Component | Examples | Benefits |
|---|---|---|
| Crops | Cereals, pulses, oilseeds | Food security, income generation |
| Livestock | Cattle, goats, poultry | Protein source, manure production |
| Fisheries | Carp, tilapia | Nutritional diversity, water use efficiency |
| Forestry | Agroforestry, silvopasture | Soil conservation, carbon sequestration |

Source: Adapted from Gupta *et al.* (2012) and Kumar *et al.* (2014)

The livestock component of the integrated farm system (IFS), comprehensively shown in Fig 2 and detailed in Table 1, includes dairy, goat rearing, sheep rearing, piggery, poultry, pigeon rearing, rabbitry, and duck rearing, which are very vital in the recycling of nutrients and income. These divergent patterns of animal husbandry play a very crucial role in maintaining the system's strength and yield. Ryschawy *et al.* (2017) pointed out that having a system with a combination of crops and livestock produced fewer greenhouse gas emissions per hectare than having specialized systems. The integration of livestock also helps in effective nutrient recycling and hence animal wastes as a source of organic manure for crop produce and reduces on the use of inorganic inputs as observed by Tracy and Zhang (2008) on integrated crop-livestock system in Illinois.

Two other examples that show the further expansion of the IFS to include fish farming and apiary reflect this natural resource concept of the system. Fish farming can be either be carried out together with crop farming, for instance, rice-fish farming which can increase both, land, and water production. Besides producing honey to complement other farm produce, apiculture also has an important function in pollination to enrich farm revenue and food production. These contribute to the general system resilience and productivity in support of Carlisle's (2014) argument on the enhanced resilience of diversified farming systems to climate variability.

Vermiculture and fodder production are two-part components that are crucial for the livestock and soil health of the IFS system. Special products mean specific quality fodder for the livestock and make the system less dependent on outside supply. Vermiculture, a process of using earthworms to decompose organic waste into valuable vermicompost, is an excellent model of the nutrient recycling principle inherent in IFS, (Sulc, &Franzluebbers, 2014). This practice also enhances the status of the soil besides availing another source of revenue from the production and sale of vermicompost and earthworms. IFS, for its seed production component, pointed out in Figure 1, is dependent on genetic resources for its sustenance. By introducing seed production, people can develop and progress locally adapted plant varieties to reduce vulnerability to biotic and abiotic stresses. This correlates well with the FAO's (2015) objectives of the conservation and sustainable use of PGRFA in line with its lead mandate.

The development of new and multiple farm enterprises in IFS also provides a strong base for adaptation to climate volatility. Comprehensive Carlisle 2014 study of the northern Great Plains of the USA concluded that the concept of diversification held more promise than monoculture farming under adverse weather conditions. This has been attributed to synergism whereby different enterprise resources are said to be symbiotic such that whatever can be lost in one enterprise resource can always be compensated by the gains in another. Moreover, resource use efficiency uplifted by IFS can also improve adaptive capacity. Lemaire *et al.* (2014) indicated that the type of management associated with integrated crop-animal systems enhances the rate of cycling nutrients and limits the rate of nutrient outflow and offsite losses. This efficiency not only saves energy and, therefore, decreases greenhouse gas emissions of agricultural production but also increases farm return on investment, and profit, creating positive economic incentives for sustainability in agriculture, (Russelle *et al.,* 2007).

### 4.2. Integrated Farming System: An Eco-Friendly Approach

#### *4.2.1. Reduced Greenhouse Gas Emissions and Carbon Sequestration*

IFS has been considered to have significant effectiveness in climate change mitigation and adaptation, and that potential is reflected in modern international policies. As shown in Table 2, various IFS practices have substantial greenhouse gas reduction potential, with agroforestry showing the highest reduction at 20-50%. FAO (2015), stresses the active participation of comprehensive techniques for climate-smart agriculture to ensure an increase in productivity while meeting the ever-rising climate change challenges locally and globally in a sustainable manner and to minimize on emission of greenhouse gases. Table 2 also highlights that improved grazing management can reduce greenhouse gas emissions by 15-40% while sequestering 0.3-1.0 Mg C ha−1 year−1. But this has the potential of being realized where there are no impediments to adoption such as no awareness, high costs at the onset, and policy factors. As indicated by Garrett *et al.* (2017), greater attention must be given regarding future research and policy incentives for the further diffusion of IFS as a sustainable intensification approach. This entails designing context-appropriate IFS models, the onset of economic instruments of incentive reimbursements for ecosystem services, and enhancing extension infrastructure for farmers to embrace integrated models, (Tarawali, 2018).

**Table 2** Greenhouse Gas Mitigation Potential of Integrated Farming Systems

| Practice | GHG Reduction (%) | Carbon Sequestration (Mg C ha−1 year−1) |
|---|---|---|
| Crop-livestock integration | 10-30 | 0.1-0.5 |
| Agroforestry | 20-50 | 0.5-3.0 |
| Improved grazing management | 15-40 | 0.3-1.0 |
| Conservation agriculture | 5-15 | 0.2-0.7 |

Source: Compiled by Thornton and Herrero (2015) and Mbow *et al.* (2014)

The development of new and multiple farm enterprises in IFS also provides a strong base for adaptation to climate volatility. Table 2 demonstrates that crop-livestock integration can reduce greenhouse gases by 10-30% while sequestering 0.1-0.5 Mg C ha−1 year−1, and conservation agriculture practices contribute an additional 5-15% reduction with 0.2-0.7 Mg C ha−1 year−1 of carbon sequestration. Comprehensive Carlisle 2014 study of the northern Great Plains of the USA concluded that the concept of diversification held more promise than monoculture farming under adverse weather conditions. This has been attributed to synergism whereby different enterprise resources are said to be symbiotic such that whatever can be lost in one enterprise resource can always be compensated by the gains in another. Moreover, resource use efficiency uplifted by IFS can also improve adaptive capacity. Lemaire *et al*. (2014) indicated that the type of management associated with integrated crop-animal systems enhances the rate of cycling nutrients and limits the rate of nutrient outflow and offsite losses. This efficiency not only saves energy and, therefore, decreases greenhouse gas emissions of agricultural production but also increases farm return on investment, and profit, creating positive economic incentives for sustainability in agriculture, (Raney, 2010).

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#### *4.2.2. Nutrient Recycling for Better Soil Health*

IFS intervenes greatly in promoting the efficiency of nutrient-cycling soil, which is central to sustainable agriculture. Many of the ideas presented in this paper can be understood in terms of the broad concept of resource recycling depicted in Fig 3 from Kumar *et al.* (2018), which shows how elements of an IFS work together to form a closed cycle and ensure that nutrients are used to the greatest extent possible and wastes are minimized. This model reveals the complex interconnection between crops, livestock, fish, and wastes grown and handled within a farm framework and owned and operated by a farm family with land, labour, capital, and energy inputs, (Ralevic *et al*., 2010).

As mentioned by Acosta-Martínez et al. (2004), IFS enhances soil microbial, chemical, and physical quality over MFS as does continuous monoculture practice, with Table 3 showing significant improvements in soil health indicators such as 40-75% higher soil organic matter and 50-100% greater microbial biomass in integrated systems. The combination of livestock with crops provides a closed nutrient recycling system, where animal droppings are used to replenish soil nutrients in organic materials. As shown in Fig 3, dung, and droppings from various livestock units (cattle/dairy, poultry, duckery, and goat) are collected and dumped in a central compost pit (FYM/VC) which serves as a source of organic matter for crop production. This corresponds to the observation made by Petersen *et al.* (2007) who noted that recycling livestock manure in an integrated farm system can address a significant proportion of the crop nutrient demands in a sustainable manner without polluting the surroundings.

**Table 3** Soil Health Indicators in Integrated vs. Conventional Farming Systems

| Indicator | Integrated System | Conventional System | Improvement (%) |
|---|---|---|---|
| Soil Organic Matter (%) | 3.5-5.0 | 2.0-3.0 | 40-75 |
| Microbial Biomass (mg C kg−1 soil) | 300-500 | 150-250 | 50-100 |
| Water Holding Capacity (%) | 25-35 | 15-25 | 40-60 |
| Aggregate Stability (%) | 70-85 | 50-65 | 30-40 |

Source: Compiled by Acosta-Martínez *et al.* (2004) and Tracy and Zhang (2008)

Furthermore, nutrient cycling in IFS is more efficient contributing to sustained fertility of the soil. As detailed in Fig 3, crop residues along with vegetable waste are used as animal feed, and as a substrate for growing mushrooms to generate further value-added products. This circular flow of resources supports the authors' earlier observations made by Maughan *et al*. (2009) that crops and livestock integration enhanced soil quality of aggregates including particulate organic matter and potentially mineralizable nitrogen soil in Illinois. The crop component then supplies the mushroom unit with spawn straw to improve the contents of the soil's organic matter even more, contributing to the 40-60% higher water holding capacity and 30-40% better aggregate stability shown in Table 3.

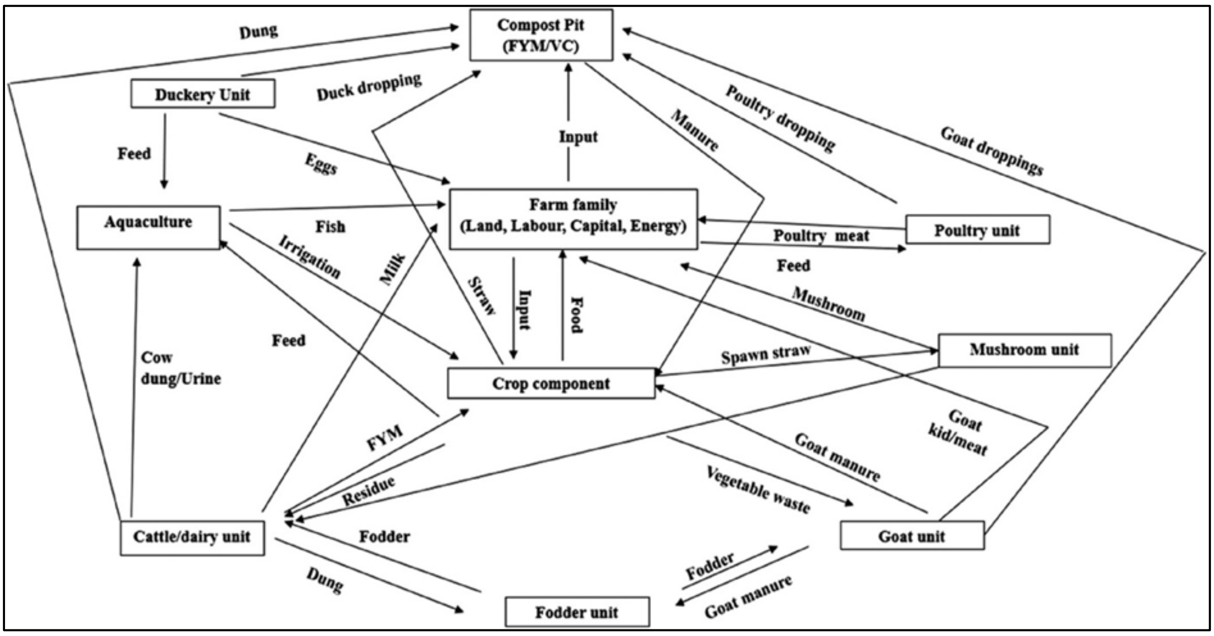


**Figure 3** Resource recycling concept of integrated farming system. Source: Adopted from Kumar *et al*. (2018)

The integrated Factorial System shown in Figure 2 has an aquaculture component that further enhances nutrient recycling in IFS. Fish production is also closely linked with crop and livestock sectors via feed and nutrient interdependence. The cattle/dairy unit provides cow dung and urine in the aquaculture while the fish waste is used to fertilize crops in crop production. This integration illustrates examples of nutrient interaction as pointed out by Lemaire *et al*. (2014) whereby managing the nutrients in systems involving crops, livestock fish creates chances for minimizing external use of inputs and at the same time realizing system productivity. Like the fodder unit illustrated in Fig 3, livestock components are accurately supported while experiencing the advantage of throughput of nutrients within the system. It is revealed that goat manure favours fodder production and the outcome support feeding numerous livestock units. This afforestation of fodder complements livestock production making the system more closed and reducing the importance of the technology in the system. The result is improved soil health and decreased environmental footprint as observed by Sanderson *et al*. (2013).

It is important to note that nutrient recycling does not only afford soil benefits as observed in IFS but other ecosystem services as well. The decreased dependence on exterior imports of nutrients proven in various interconnections in Figure 2 reduces water pollution from nutrient leaching and run-off. Furthermore, due to better conditions of soil structure provided by the IFS, the storage of carbon within the system has also been made possible to mitigate climate change. Yet, achieving most of these benefits comes with many challenges that need proper management and working under different circumstances valid in that region. According to Bell *et al*. (2014) and Sulc and Franzluebbers, (2014), there is a need to innovate crop animal systems to enhance the productivity of the farming system as well as its sustainability.

### 4.3. Factors Contributing to Low Livestock Production and Their Impacts

#### *4.3.1. Limited Access to Quality Feed and Water Resources*

Among the key causes of low livestock production is scarcity of proper feed and water which affects animals' nourishment, whether or not, and performance. Limited availability of feed is a perennial problem in many parts of the world, especially in the arid and semi-arid zones of the tropics and subtropics where prospects for increasing the productivity of livestock are highly likely to be limited by feed resources. Ralevic *et al*., (2010) submit that forage availability influences the livelihood status of the large livestock holdings in the northern highland of Ethiopia due to changes in feed quantity and quality about the level of animal performance all year round. This is made worse by climate change impacts, specifically the changes in rainfall distribution and particular frequency and intensity of droughts that are especially prevalent among several livestock-rearing countries, Veysset *et al.,* (2014). Lack of feeding stuff, not only where water is in short supply to provide directly for animals to drink or grow fodder crops also, makes complications of feeding materials. Livestock keepers have little choice but to feed livestock on high fiber, low-quality feeds like crop residues and natural pastures that may not supply the necessary nutrients, especially during critical stages of production like lactation or growth, (Ralevic *et al.,* 2010).

The effects of limited pasture and water supply are highly destructive and pervasive on the subjects. First of all, it causes reduced feed intake, consequently, it results in decreased growth rates in young animals, less milk production in the dam, and compromised reproductive performance. This can be realized in terms of lower income to livestock keepers and reduced access to ASFs by households, (Peterson *et al*., 2020). Second, poor feed leads to a poor immune system in animals, which makes them easily attacked by diseases and parasites. This not only raises mortality rates but also, increases the likelihood of veterinary expense and possible zoonotic disease. Thirdly, in the process of looking for feed and water, the animals may over graze in the same area causing soil depletion and loss of biological diversity. , according to Bale *et al.* (2007), to ensure a sustainable food production system is developed to meet the challenge of RFI that handles livestock yet respects the remaining natural resource base and ecosystem services. To overcome the challenge of limited feed and water, it is imperative to review resource mobilization, and germplasm improvement through the development of drought-resistant forage varieties as well as innovations in the management of water, (LPP and LIFE Network, 2010).

#### *4.3.2. Prevalence of Animal Diseases and Inadequate Veterinary Services*

This study has also shown that diseases affecting animals and lack of adequate veterinary services are other determinant factors that slow livestock production in many regions of the world. Animal diseases go along with direct losses due to deaths and declines in productivity or reproduction in addition to personnel losses, but also with indirect losses due to trade barriers and public health risks. Leyland *et a*l (2014) have pointed out that due to the apparent shortage of cheap and quality services from qualified veterinarians, many livestock especially from the rural areas mostly from the developing world are at risk from both regular diseases and other embryonic diseases. This is accompanied by poor healthcare systems, especially inadequate disease surveillance, diagnostic, and inadequate funding of disease control programs. The issue is especially worrying for sustaining efficient VS in remote and marginalized zones, in which typical modalities of VS provision are ineffective or too expensive to implement, Peterson *et al.,* (2020).

Consequently, the effects of animal diseases on livestock production are enormous and incalculable. Firstly, disease. Contributes to animal productivity in two ways; an immediate effect due to diseases that decrease feed conversion ratio, growth rate, and reproduction. For example, foot and mouth disease which is rife in many areas of the third world can lead to loss of production affecting milk and weight gain in affected animals, (LPP and LIFE Network, 2010). Secondly, the disease control directional imperative often results in stringent international trade policies, which deplete consumers' market for livestock products and income sources. Thirdly, they are accompanied by high public health concerns that result in decreased demand for animal products coupled with high costs of treatment. These are issues that can be addressed only under a long-term and systematic approach involving enhancement of the veterinary infrastructure; upgrading and enhancing the disease surveillance and reporting; and extension of the community animal health services. Hence, as emphasized by VSF International (2018), CB animal health workers can significantly contribute to improving existing official veterinary networks as informal primary animal health care service providers.

*4.3.3. Genetic Limitations and Lack of Breeding Programs*

The realized genetic potential of livestock by National Research Council (2010) is one of the key factors that define productivity, and there is evidence that many livestock populations have genetic liabilities that affect their productivity, predominantly in developing countries. Here, it is clear that low levels of livestock production remain observed due to a lack of systematic breeding programs, and limited availability of improved breeding stock, (Martin, 2016). Conventional breeding programs fail to provide the required amount of structure for meaningful progress in improving genotype and a majority of smallholder farmers do not get exposure to artificial breeding techniques or quality breeds. This obliges animal breeding for productivity improvement to consider at the same time the conservation of local breeds that are valuable for their disease resistance and their adaptability to the local environment, (National Research Council, *et al*., 2010).

They indicate that the consequences of genetic restrain in livestock are severe and enduring. Firstly, animals with poor breeding values for production traits including growth rate, milk production, and or egg production are in effect lower performers, even when well-fed and well-managed. This leads to poor overall farm yields and less income for the livestock producers. Second, the current gene pool of the identified livestock species is relatively small, which may engender them to diseases or environmental conditions, which may work to be dire given diseases or climatic incidences, (Gill, Singh, and Gangwar, 2009). Thirdly, the failure to satisfy the market requirements for certain product attributes (for instance milk fat, meat elasticity) reduces the ability to enter superior value markets. These issues need to be managed comprehensively, mainly through the establishment of community-based breeding projects, enhanced AI service delivery, and conservation of local breed genetic resources. Ahuja *et al.* (2008) describe the success story of the Kuroiler chicken in India pointing out that better breeds can increase the production and income of smallholders if properly bred and disseminated to the target population along with necessary follow-up services.

*4.3.4. Limited Market Access and Value Chain Development*

Market access and especially weak and rudimentary value chains reduce the well-being of livestock, especially those smallholder producers in remote areas. Concisely in the opinion of Ponnusamy and Devi (2017) are of the view that the market failures lead to low farm gate prices of the livestock products, which discouraged the farm producers from accessing technology and innovation. Added to this is inadequate infrastructure, high transaction costs, and lack of adequate market information that they need for their participation to be effective within the formal marketplace, (Gill, Singh, & Gangwar, 2009). Moreover, many livestock products including milk and meat are perishable hence they need quality and functioning cold supply chains and processing systems that are absent or deficient in the rural areas of the growing economies.

The effects of a restricted market and unsustainable value chain on livestock production have been severe. To begin with, market access or appropriate pricing for their products hinders income generated by livestock keepers, and limits capital outlay for better stock management. This in turn leads development of a cycle in productivity and income whereby there is low productivity and in turn low income. Secondly, natural production has negative impacts such as overproduction and inadequate pricing since market production is rare, (Liebman *et al.,* 2018). Third, weak value chains greatly reduce the capacity for value enhancement and employment generation in the rural sector, dampening rural economic development in their totality. Solving such issues involves recognition and support of the physical structures in rural places, the market information and assembling services, and packaging facet/producer organization/ value addition via processing and product differentiation. According to Randolph *et al*, (2007), market access and value addition can help promote livestock production for poverty reduction and better nutrition in the developing world.

*4.3.5. Environmental Constraints and Climate Change Impacts*

According to studies by Liebman *et al.,* (2018), several factors evident environmentally have continued to act as constraints to livestock production systems with further aggravation of climate change. In Turner and Saddler's opinion, the existing pressures contributing to the impacts of climate change have negative consequences for livestock-producing systems including African and South Asian countries. Temperatures have been increasing; rainfall and snowfall occurrence varies, and storms have increased modifying feed and water requirements, health and production of animals and livestock systems. However,Gil, Siebold, & Berger, (2015) affirms that the livestock sector itself is a major source of emissions, mainly through: enteric fermentation, manure, and changing land use for feed production and grazing. The fact that livestock are both victims and culprits in climate change makes it important to balance the issues of adaptation and mitigation in livestock development, (Martin *et al*., 2016).

Consequently, ECO consideration and climate variation effects on livestock production are mainstream, numerous, and escalating. Firstly, variations in temperature and amount of rainfall are constraining the growth of pastures and rangelands thereby reducing the feed resources for grazing livestock. These can result in decreased efficiency in resource utilization, competition over space, and disagreement on how the space is to be used efficiently. Secondly, climate change affects the distribution and incidence of diseases and parasites affecting livestock; expect the effect of warm temperatures to increase the spread of vectors and vector-borne diseases to new regions, (Gil, Siebold, & Berger, 2015). Thirdly, heat stress in animals can lower feed intake, lower reproductive performance, or even death rates in animals that are selected for high production, being less well adapted to heat. Solving these problems is possible only with the help of adaptation measures, for example, the creation of heat-tolerant breeds the enhancement of water conservation, and the reduction of the negative impact of livestock farming on the environment. According to Sanderson *et al*. (2013), integrated crop-livestock systems possess likely prospects of increasing the level of resilience from environmental shocks despite improving the existing resource utilization.

**Table 4** Comparative Analysis of Livestock Production Systems Across Selected Countries

| Country | Main Livestock | Production System | Annual Meat Production (1000 tonnes) | Annual Milk Production (1000 tonnes) | Average Herd Size | Feed Availability (tonnes DM/ha/year) | Disease Prevalence (%) | Market Access (% of farmers) | Climate Vulnerability Index (0-100) |
|---|---|---|---|---|---|---|---|---|---|
| Ethiopia | Cattle, Goats | Pastoral/Mixed | 1,400 | 4,500 | 5-10 | 2.5 | 35 | 40 | 75 |
| India | Cattle, Poultry | Mixed | 7,700 | 187,000 | 2-5 | 3.2 | 25 | 60 | 65 |
| Brazil | Cattle | Extensive/Intensive | 26,500 | 34,000 | 50-200 | 5.8 | 15 | 85 | 45 |
| USA | Cattle, Poultry | Intensive | 48,000 | 99,000 | 100-1000 | 8.5 | 5 | 95 | 30 |
| China | Pigs, Poultry | Intensive/Mixed | 88,000 | 32,000 | 10-500 | 6.2 | 20 | 80 | 55 |
| Kenya | Cattle, Goats | Pastoral/Mixed | 650 | 5,000 | 5-15 | 2.8 | 40 | 45 | 80 |
| Australia | Cattle, Sheep | Extensive | 4,900 | 9,000 | 100-5000 | 4.5 | 10 | 90 | 50 |
| France | Cattle, Poultry | Intensive/Mixed | 5,400 | 24,000 | 50-200 | 7.5 | 8 | 92 | 35 |
| Nigeria | Cattle, Goats | Pastoral/Mixed | 1,500 | 600 | 10-50 | 3.0 | 45 | 35 | 70 |
| Argentina | Cattle | Extensive/Intensive | 6,000 | 11,000 | 200-1000 | 6.5 | 12 | 88 | 40 |
| Netherlands | Cattle, Pigs | Intensive | 3,200 | 13,000 | 50-500 | 9.0 | 7 | 95 | 25 |
| Sudan | Cattle, Camels | Pastoral | 1,100 | 4,000 | 20-100 | 1.8 | 50 | 30 | 85 |
| New Zealand | Cattle, Sheep | Extensive/Intensive | 1,500 | 21,000 | 100-2000 | 8.0 | 9 | 93 | 35 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Mexico | Cattle, Poultry | Mixed/Intensive | 7,000 | 12,000 | 20-200 | 5.0 | 18 | 75 | 60 |
| Tanzania | Cattle, Goats | Pastoral/Mixed | 700 | 2,500 | 5-20 | 2.2 | 42 | 38 | 78 |

Sources:

Meat and milk production data: FAO (2020)

Herd size and production system: Derived from Herrero *et al.* (2012)

Feed availability: Estimated based on Martin *et al.,* (2016) and regional data

Disease prevalence: Approximated from Leyland *et al.* (2014) and regional reports

Market access: Estimated based on Ponnusamy and Devi (2017) and country-specific studies

Climate Vulnerability Index: Adapted from Thornton and Herrero (2015) and global climate vulnerability assessments

Note: DM = Dry Matter. The numbers used herein are estimates to indicate the range and issues that have been observed in various LSs worldwide. The values can, however, differ depending on sub-geographic locations within a country as well as any recent changes.

This table 4 gives comprehensive information on livestock production characteristics and problem issues in the selected countries showing the whole picture of livestock production characteristics and systems globally. Ideally, the data presented here highlight huge differences across the countries in terms of the scale and efficiency of livestock production and the extent of market integration indicating several factors at play in determining the pattern of livestock production.

### 4.4. Sustainable Solutions for Improved Agricultural Output

#### *4.4.1. Adoption of Integrated Crop-Livestock Systems*

According to (Ghotge *et al*., 2004) integrated crop and livestock production systems, therefore, are a viable sustainable approach to increasing yields and balancing stewardship of the environment. As illustrated in Fig 4, this transition involves moving from less sustainable monoculture practices to more diverse, integrated systems that incorporate both crops and livestock. These systems profit from the complementary relationships between crop and animal production to enhance the efficiency of resource utilization, minimal reliance on inputs, and increased system productivity of farming. As stated by Sanderson et al. (2013), ICLS throughout North America has shown considerable capacity regarding improving soil quality, nutrient retention, and farm income. Fig 4 highlights how this transformation is supported by various programs and initiatives, including training, field days, seminars, mentorships, and advising programs.

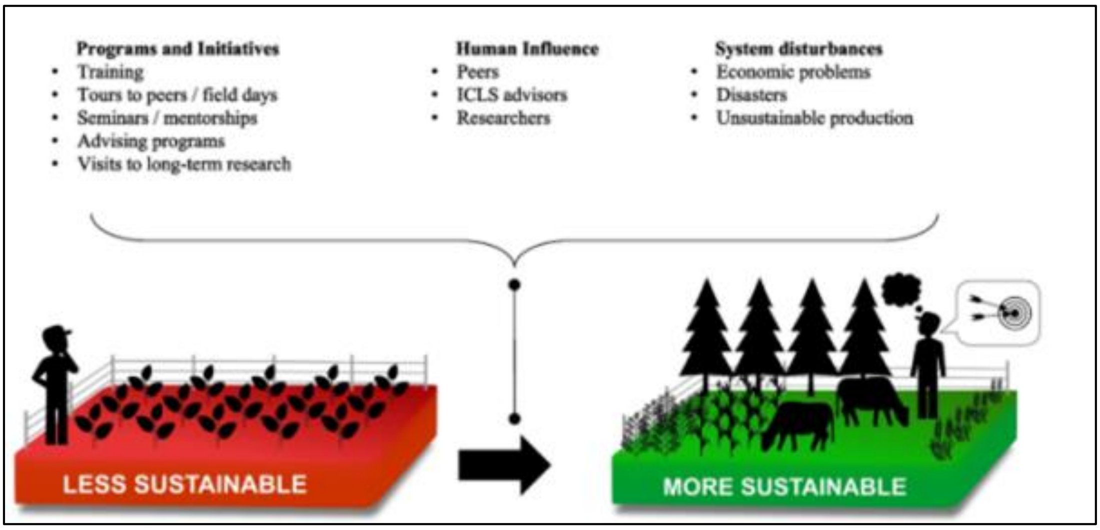


Figure 4 Turning points towards more sustainable agroecosystems. Source: Moojen *et al.,* (2018)

It can be more conducive to recycling nutrients, thinking, that animal manure acts as organic fertilizer to crops while crop residues and by-products are fed to animals, (Nie *et al.,* 2016). While this recycling concept may make a system less dependent on synthetic inputs, cut production costs, and even have positive effects on the long-term soil health, Fig 4 shows that the transition faces potential system disturbances such as economic problems, disasters, and unsustainable production practices. However, human influence through peers, ICLS advisors, and researchers, as depicted in Fig 4, can help overcome these challenges.

In addition, some of the advantages of adopting ICLS are resilience to environmental and economic shocks that go beyond resource efficiency. Supporting the earlier study of Ryschawy *et al*. (2012), the present study showed that MLF held more economic resilience and efficiency and expended lesser environmental index than the S systems in France. Due to the notion of diversification embedded in ICLS, there are many different sources of income, or contingencies to offset poor production or unfavourable market conditions. Furthermore, how integrating livestock in cropping systems could increase their ability to cope with climatic fluctuations by improving soil attributes resulting from inputs of organic matter. However, the successful experience indicates that the implementation of the system must be managed and adapted to the local circumstances. Lemaire *et al*. (2014) also call for systemization in the design of ICLS given the close relations between crops, animals, and the surroundings. This involves improving the coordination of crop sequence, grazing, and nutrient cycling to address the integration between system components and the inter-organization of opportunities and constraints, (Ghotge *et al*., 2004).

Enhancement of Genetic Resources and Breeding Programs

Enhancing the genetic base of the animals and plants that feed humanity is an important element of enhancing agricultural productivity through increased efficiency. Meaning improved genetic resources have the potential to increase production, disease, and stress resilience, and resource use efficiency. In its recent report, the FAO (2015) has underlined the importance of the development and conservation of animal genetic resources to address the issues of food security and climate change adaptiveness. According to Food and Agriculture Organization of the United Nations, (2010), systematic mating schemes that aim for both high production performances as well as for protective and stability factors are crucial for the generation of animal populations that can sustain themselves under various and/or fluctuating production systems. Such an approach is especially useful in the context of smallholder farming systems, especially when animals are to perform a variety of tasks and withstand harsh environments, (IAASTD, 2008).

That is why it is appropriate to assume that the directions for the progress of productive genetics and genetic improvement can be based only on the use of traditional and advanced breeding technologies as well as on biotechnological methods. As Ahuja *et al.* (2008) presented the example of Kuroiler chicken in India is extremely sensitive to the productivity and profits of the small farmers: when improved breeds are used. In the case of the Kuroiler, a dual-purpose breed reared for small-scale backyard poultry production, it revealed better growth and egg performances than the local breeds but with the advantage of being suitable for low input systems. Yet, the emphasis on the improvement of selected genotypes is essential to prevent the loss of valuable genetic resources that are responsive to local environmental conditions. As highlighted by Leyland *et al.* (2014) in the evaluation of smallholder breeding programs, this concept stands as an opportune strategy that will enable the generation of locally adapted breeds as well as ensure genetic variation. These programs involve farmers in the selection process to increase anarchy to breeding objectives that will meet the needs and environment of the region. While these efforts can help to gradually improve the genetic merit of Bos taurus, adding advanced reproductive technologies and genomic selection tools can enhance concurrent genetic progress and maintain critical adaptive genes, (Food and Agriculture Organization of the United Nations, 2010).

### *4.4.2. Improvement of Feed Resources and Nutrition Management*

In this regard, Nie *et al*., (2016) explains in their study that increasing availability and quality of feed resources remain important inputs in formulating strategies to improve livestock productivity and viability. Feed shortage is amongst the most constraint-reducing factors affecting livestock production, especially in the arid and semi-arid zones. Solving this question involves innovation in research that focuses on forage production such as drought-resistant varieties of grasses, better management of the grazing lands, as well as better use of crop stalks and other residues from agro-industries. As argued by Duru, &Therond, (2015), even though forage productivity and quality have been cited as a major constraint limiting livestock productivity in smallholder systems, there is strong evidence that it has the potential to effectively influence livestock performance. These are the availability of better forage varieties, practical measures like silage and hay production, and selective feeding during periods of scarcity of feed resources, (Ewing *et al*., 2004).

The application of more enhanced nutritional techniques can increase the feed conversion ratio and animal performance beyond the existing feed available in the ration. Individual animal feeding, which avoids overfeeding to enhance feed efficiency while formulating feeding plans, can also reduce waste. Regarding the livestock feed system, Petersen *et al.* (2007) agree with the concept of nutrient flow management in the whole farm system terms that phased feed production for animal nutrition and manure management the interconnected components. Such an integrated system can result in higher Net Nutrient Balance, lower nutrient surface output, and improved productivity. Furthermore, insect or single-cell protein feeds for livestock imply that they should feed on something other than conventional feeds, providing an opportunity to improve the sustainable intensification of livestock feeding systems. These new feeds can be good sources of proteins and/or substitute human food resources and/or valorize organic waste flows, (Alders, 2012).

*4.4.3. Strengthening Animal Health Services and Disease Management*

Increased accessibility to health services as well as efficiency in disease control is crucial for increasing livestock production, as well as decreasing accumulative economic losses due to diseases. Leyland *et al* (2014) opined that CAHWs are valuable assets in basic veterinary health services and disease monitoring and are best suited to function in the formal veterinary systems in rural areas. This strategy has been very helpful in areas that are hard to reach and are considered as the periphery areas and thus cannot support the normal veterinary service delivery system. Because CAHWs are recruited from the catchment area, they can train local community members on basic animal health care and disease diagnosis thus ensuring early reporting of diseases that result in poor health of the herd and production, (Alders, 2012).

Hearing impairment disease management requires the use of multiple components of prevention, surveillance, and interventions. The main livestock diseases cause huge losses and vaccination programs, if efficiently launched, can minimize such diseases among animals. Nevertheless, according to VSF International (2018), such programs require consequent cold chain management, vaccine quality, and proper administration. Building up an effective and efficient veterinary system and diagnostics form an important factor in the early and fast recognition of diseases. This involves spending on laboratory equipment and facilities, increasing training for veterinary personnel, and accreditation of disease reporting. Furthermore, Duru, & Therond, (2015) found in their study that there has been rising importance for the One Health concept, which focuses on the role of the specific link between animals, humans, and the surrounding environment in fighting various health problems, including those of zoonotic etiology. As explained by (Ewing *et al.*, (2017), this integrated approach can improve the efficiency of disease prevention and control whilst creating favorable conditions for the general public health and the sustainable state of the ecosystems.

*4.4.4. Development of Sustainable Market Linkages and Value Chains*

Aids market access and to ensure the resulting productivity improvements do translate into tangible benefits to the farmer, it is essential to focus on support for greater improvements in the efficiency of value consumer chains. Ponnusamy and Devi (2017) have emphasized that integrated farming system approaches can go a long way to increase the farmers' income through increases in product diversification and better market access. Some of these are farming organized through farmer groups or cooperatives which enhances bargaining power and transaction cost for smallholder producers through collective marketing. Another potential benefit arising from the CPF is the establishment and expansion of local processing centers and cold chain infrastructure to enhance the quality of products and coverage for perishable livestock products, (IAASTD, 2008).

These opportunities include product differentiation through value addition and upgrading on quality that can make farmers gain access to better markets and more income. This may encompass the adoption of value-added products through the diversification of products from traditional livestock breeds or production methods followed in the smallholder systems, and accreditation programs that meet market requirements. It is perceived that to transform livestock productivity and market access, the authors stress the need for performance on a value chain basis as proposed by Randolph *et al.* (2007). This is done to control constraints at zones of the flow chain, including input provision and manufacturing, processing, marketing, and use. In addition, initiatives like the use of mobile applications for market data and or electronic trading, and other value-added services can help to bridge some of the information gaps and offer producers a more direct link to consumers, or processors. Such strategies in market development can enhance livestock value chain sustainability and open up more possibilities for smallholder livestock producers to realize potential benefits arising from productivity and product quality improvements, (Duru, & Therond, 2015).

## 5. Conclusion

Finally, under the pressure of the constantly rising global demand for food and with the progressing deterioration of the environment, the livestock sector is at a crossroads. This broad analysis has shed light on various and complex problems that livestock farming everywhere faces, from existential hurdles of feed deficits and diseases to novel risks of climate change and market risks. Indeed, as this report shows, a fabric of possibilities has been woven despite the problems and a roadmap for enhancing the food security and economic returns from livestock has been provided. The utilization of the composite system of crop and animal production has shown good potential in terms of improving the use efficiency of resources and farm stability. Integrated to optimally, crop and animal production improve output and enhance the production base, and the system does not harm the soil thereby reducing any negative impact on the environment. The improvement of genetic resources through Tropical breeding programs has been widely credited for the production of livestock breeds, with the capacity to operate at high levels as well as withstand harsh and often unfavorable ecological conditions. ALBC supports this genetic improvement in that along with it came the conservation of Indigenous, unavoidable for future adaptations and food security.

It is evident from the present review that the process toward an optimal and sustainable production of livestock is not straightforward and does not follow a similar line in different systems. It instead presupposes complexity of context, and an ability to coordinate, while also respecting both legacy knowledge and new technologies. The case histories and rationale presented in this review also suggest that better livestock production, environmental protection, and livelihoods for marginal communities are not mutually exclusive goals. However accessing this potential on a global level depends on solidarity from policymakers, researchers, farmers, and consumers. Over the next decade and beyond, the livestock sector is poised to play an essential role not only in the increased production of ASF but also in the attainment of sustainable development goals revolving around poverty reduction, food insecurity, and climate change. The path to realizing this vision will not be easy, but with combined effort and effort, the livestock sector can be more sustainable and productive.

### *Recommendations*

Based on the comprehensive analysis conducted in this review, several key recommendations emerge for enhancing livestock productivity and sustainability:

- 1.Promote Integrated Farming Systems: Far-reaching policy reforms and agricultural extension services should encourage and widely adopt integrated crop-livestock production systems. This includes undertaking new modeling to support integrated systems by zones, farmer training and assistance for changing to integrated livestock–crop disease management systems, and offering subsidies or payment for ecosystem services.
- 2.Invest in Genetic Improvement and Conservation: The use of genetic improvement should therefore be balanced. Additional resources should be assigned to create breed development and breeding projects in various communities to improve and enhance suitable, high-performing breeds. At the same time, for-preventive conservation programs have to be made for in-situ and ex-situ conservation of Indigenous livestock genetic resources. It will be thus possible to obtain productivity improvements for the next impregnation season while at the same time ensuring that genetic variation is enhanced in preparation for the next breeding season.
- 3.Enhance Feed and Nutrition Strategies: It is, therefore, important that more resources are invested towards the development of high-yielding forage plant varieties that can survive in drought-stricken regions of KwaZulu Natal. Further, extension support should be provided to farmers on best practices in pastures, conservation (silvage making), and selective supplementation. Efforts should be made for the promotion of precision feeding technologies developed for smallholder farmers and feed sector improvement for better feed conversion efficiencies.
- 4.Develop Sustainable Market Linkages: Amenities should then be extended to the farmer cooperatives and other producer organizations to improve market muscle power. The establishment of appropriate storage facilities and efficient physical transport infrastructure remains a necessity for enhancing market accessibility in the agricultural sectors. Also, aid must be rendered for the establishment of bio-secure facilities for the processing of livestock products that include methods of enhancement, which will increase the shelf life of livestock products.
- 5.Promote Climate-Smart Livestock Practices: This is an ideal practice that requires governments through CLAs to offer subsidies, carbon credits, or payments for ecosystem services which encourages the adoption of climate-smart livestock innovations. This includes strengthening the adoption of better capability of manure, better practice in Agroforestry in pastoral-based systems, and renewable energy in animal-based operations.
- 6.Foster Public-Private Partnerships: Promote partnerships between government departments, academic or research organizations, and companies with an interest in the livestock domain. This could encompass

collaboration for technology innovation and extension, enhancing value chains, and innovation for markets influencing smallholder farmers.
- 7.Implement Supportive Policy Frameworks: Devise definite national policies on livestock that include consideration of the sustainable development agenda. These policies should help clarify the legal rights to use the land for grazing, set principles for increased production efficiency, and create an environment conducive to the development of the livestock sector.

Through the adoption of these recommendations, stakeholders will be able to help build the capacity to achieve a more productive, resilient, sustainable livestock sector that would be able to feed the increasing global demand for animal-source foods, empower livelihoods, and protect the environment.

### *Future thrust areas*

As the livestock sector continues to evolve in response to global challenges and opportunities, several key areas emerge as critical for future research and development efforts:

- *Precision Livestock Farming for Smallholders*: Strengths from the use of precision farming technologies have been witnessed more in large-scale commercial farms while smallholder ones have limited practice of adoption and implementation. Hence, there should be continuous research on affordable technologies for precision farming that are easily adaptable by small-scale farmers. These could also embrace smartphone-based applications used in animal disease surveillance, cost-effective sensors in environment and physiological health data gathering, and artificial intelligence decision support systems for feeding and breeding. The idea is to apply what has increasingly become known as 'precision agriculture', improving agricultural efficiency at the subsistence farmer level.
- *Climate-Resilient Livestock Systems:* With climate change posing an existential threat to many livestock production systems, particularly in vulnerable regions, there is an urgent need for research into climate-resilient livestock breeds and management practices. This ranges from simple approaches such as breeding for heat-tolerant cattle through conventional and genomics selection, to complex strategies that comprise housing and cooling systems that could address heat stress challenges. Moreover, there is the need to consider feed production systems that are capable of performing well under climate change conditions such as drought-tolerant forages and other unconventional feed resources.
- *Circular Economy Approaches in Livestock Production*: The next step for research would be to identify new strategies towards the same cycle closure in livestock production. This includes advancing technologies in the anaerobic digestion of manure and conversion into usable products, examining the possibility of insects and other novel protein sources for the animal's feed, as well as the utilization of livestock in utilizing other agricultural and food-based waste products. The goal is to shift from a traditional livestock chain where the output is meat, to a circular livestock chain in which waste becomes a resource.
- *Advanced Reproductive Technologies for Genetic Improvement*: The literature review showed that although there has been great improvement in the breeding of livestock, there is still ample area for improvement through the use of sophisticated methods of reproduction. Future research should improve on and modify procedures like gene editing, embryo transfer, and semen sexing in different tried and tested livestock species and production settings. Special emphasis should be put on the genetic tendency to promote disease tolerance, feed conversion, and ability to perform under different environmental conditions.
- *Sustainable Intensification of Pastoral Systems*: Extensive pastoral livestock systems are typically under-represented in research on agriculture and development, yet they are highly significant in feeding the world's population, and in managing the world's largest rangelands. Future research on these systems should therefore aim at identifying long-term productive intensification processes that will not harm the natural resource base or negate the culture of these peoples. This could encompass identifying new ways and means of managing rangelands, creating applications for the use of mobile technology in the remote management of herds, and identifying new uses for pastoral products.
- *Blockchain and Digital Technologies for Livestock Value Chains:* The opportunities offered by these technologies such as blockchain and others have not been fully harnessed in livestock value chains. Therefore, future research should focus on the ability of these technologies to be harnessed to fully enhance traceability; bring efficiency in dealing with food safety challenges; minimize the transaction costs associated with the chain; and, avoid undue polarization of benefits in the chain. It entails the implementation of smart contractual arrangements for the establishment of animal identification and product traceability, the formation of decentralized producer and consumer relations, and smart contracts in live staple marketing.
- Livestock's Role in Bioeconomy and Renewable Energy: It is perhaps rather amusing that despite the shift towards the bioeconomy, the contribution of livestock to the generation of renewable energy and bio-resources

has remained an understudied area. Further empirical studies should be carried out on exploring new models of synergy between livestock farming and biogas production, the applicability of animal by-products in the generation of sustainable raw materials, and the possibility of livestock participating in, and benefiting from, renewable electricity generation.

- Social and Economic Research on Livestock System Transitions: It is important therefore that with changing trends in livestock systems in different regions in their efforts to meet the sustainability challenges, there is a need for more social and economic analysis to support such transformation. This involves analysis of the social and economic effects of new technologies and practices on rural dwellers, identifying factors inhibiting livestock practice adoption among smallholder farmers, and formulating policies that foster sustainable livestock development.

Hence, the emphasis in research and development initiatives on identified thrust areas can enable the livestock sector to prepare for the challenges posed by current realities in the 21st century including food security, environmental conservation, and rural development.

## Compliance with ethical standards

*Disclosure of conflict of interest*

No conflict of interest to be disclsoed.

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