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Enhancing the Quantity and Quality of Livestock Production through Improved Management Practices and Modern Technologies in Afghanistan

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Abstract
Livestock production plays a key role in Afghanistan's agriculture, rural livelihoods, and food security; however, productivity remains below regional and global averages. This review examines how improved management practices and modern technologies can enhance livestock production under Afghanistan's socio-economic and agro-ecological conditions. Relevant peer-reviewed publications, reports of international organizations, and national policy documents were reviewed. The analysis focused on feeding and nutrition, animal health, housing and welfare, genetic improvement, record keeping, and digital livestock technologies. The review indicates that low-quality feed resources, limited veterinary services, poor infrastructure, and low genetic potential are major constraints to livestock development. Evidence suggests that balanced feeding, improved housing, community-based breeding programs, and digital management tools can increase milk and meat production, improve reproductive performance, reduce disease incidence and mortality, and enhance animal welfare and farm efficiency. However, adoption remains limited due to financial, institutional, infrastructural, and sociocultural barriers. The study concludes that integrating improved management practices with locally adapted technologies, supported by effective policies, capacity building, and public–private partnerships, is essential for sustainable livestock development and improved rural livelihoods in Afghanistan.

Keywords: Afghanistan, Livestock, Productivity, Management, Modern Technologies, Sustainable Agriculture

افزایش کمیت و کیفیت تولیدات حیوانی از طریق بهبود شیوه‌های مدیریتی و کارگیری تکنالوژی های نوین در افغانستان

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خلاصه
تولیدات مالداری نقش اساسی در زراعت، معیشت روستایی و امنیت غذایی افغانستان ایفا می‌کند؛ با این حال، میزان بهره‌وری آن همچنان پایین‌تر از اوسط منطقه‌ای و جهانی است. این مقالهٔ مروری بررسی می‌کند که چگونه شیوه‌های بهبودیافتهٔ مدیریت و تکنالوژی‌های نوین می‌توانند تولیدات مالداری را در شرایط اجتماعی، اقتصادی و بوم‌شناختی زراعی افغانستان ارتقا دهند. برای این منظور، مقالات علمی داوری‌شده، گزارش‌های سازمان‌های بین‌المللی و اسناد پالیسی ملی مورد بررسی قرار گرفتند. تحلیل بر مدیریت تغذیه و جیره، صحت حیوانات، جایگاه و رفاه حیوانات، بهبود جنتیکی، ثبت و نگهداری سوابق، و تکنالوژی‌های دیجیتالی مالداری متمرکز بود. نتایج این مرور نشان می‌دهد که منابع غذای با کیفیت پایین، دسترسی محدود به خدمات وترنری، زیربناهای ضعیف و ظرفیت جنتیکی پایین از مهم‌ترین محدودیت‌های توسعهٔ مالداری در افغانستان به‌شمار می‌روند. شواهد موجود نشان می‌دهد که تغذیهٔ متوازن، بهبود جایگاه نگهداری، برنامه‌های اصلاح نژاد مبتنی بر جامعه و ابزارهای مدیریت دیجیتالی می‌توانند تولید شیر و گوشت را افزایش داده، عملکرد تولیدمثلی را بهبود بخشند، میزان بروز بیماری‌ها و تلفات را کاهش دهند و رفاه حیوانات و موثریت فارم را ارتقا بخشند. با این وجود، به‌کارگیری این روش‌ها و

تکنالوژی‌ها به دلیل موانع مالی، نهادی، زیربنایی و اجتماعی ـ فرهنگی همچنان محدود است. این مطالعه نتیجه‌گیری می‌کند که ادغام شیوه‌های بهبودیافتهٔ مدیریتی با تکنالوژی¬های سازگار با شرایط محلی، همراه با حمایت از طریق پالیسی‌های مؤثر، ظرفیت‌سازی و مشارکت‌های بخش دولتی و خصوصی، برای توسعهٔ پایدار مالداری و بهبود معیشت روستایی در افغانستان ضروری است.

کلیدی‌ت کلیدی: افغانستان، مالداری، بهره‌وری، مدیریت، تکنالوژی‌های نوین، زراعت پایدار

Introduction

Livestock production constitutes a central pillar of Afghanistan's agricultural economy and rural livelihood systems (FAO, 2019). A substantial proportion of rural households rely on livestock to fulfill essential nutritional requirements through the supply of meat and dairy products and to generate income from animal-derived outputs such as wool and hides ،to provide draft power for crop production, and to serve as a critical source of financial security during periods of economic and environmental shocks (FAO, 2019). Livestock production systems in Afghanistan are predominantly characterized by the rearing of small ruminants, particularly sheep and goats, alongside cattle and poultry, which collectively dominate the national livestock sector (FAO, 2019; World Bank, 2019).

Despite its significant contribution to rural livelihoods and national food security, livestock productivity in Afghanistan remains substantially below both regional and global averages (World Bank, 2014). Empirical evidence suggests that this productivity gap reflects a complex interplay of structural, institutional, and environmental constraints. First, suboptimal feeding and nutrition practices —often characterized by reliance on low-quality communal pastures and inadequate supplementation undermine animal growth, reproduction, and lactation performance (FAO, 2018). Second, the widespread prevalence of infectious and parasitic diseases, coupled with limited disease surveillance and preventive health programs, results in high morbidity and mortality rates that further depress productivity (MAIL, 2022). Third, the genetic potential of the national livestock population remains low, as indigenous breeds are rarely improved through systematic breeding programs or access to high-yield germplasm (FAO, 2018).

Compounding these biophysical limitations are weak veterinary and extension services, which constrain farmers' access to essential animal health care, technical knowledge, and productivity-enhancing inputs (MAIL, 2022). Access to formal markets and agricultural inputs is also restricted by poor infrastructure, insecure supply chains, and limited rural service provision, thereby reducing incentives for investment in improved livestock management (World Bank, 2014). Furthermore, Afghanistan's livestock sector is increasingly vulnerable to climate change impacts: rising temperatures, recurrent droughts, progressive rangeland degradation, and intensifying water scarcity exacerbate feed shortages and elevate stress on animals, with negative consequences for reproductive efficiency and overall productivity (Thornton & Herrero, 2015). Collectively, these multifaceted challenges underscore the need for integrated policy interventions that simultaneously address animal health, genetics, feed systems, service delivery, and climate adaptation strategies in order to sustainably enhance livestock productivity in the country.

At the global level, the adoption of improved livestock management strategies and advanced technologies—including precision livestock farming, smart agriculture applications, and digital decision-support systems—has demonstrated significant potential for improving animal productivity, welfare, and sustainability (Banhazi et al., 2012; Berckmans, 2017). However, the adoption of these innovations in Afghanistan remains limited. Therefore, this narrative review aims to examine the opportunities and challenges for improving livestock productivity in Afghanistan by focusing on six key areas: (1) feeding and nutrition management, (2) animal health and disease control, (3) housing and

animal welfare, (4) genetic improvement and breeding programs, (5) record-keeping and farm management practices, and (6) the application of precision livestock farming and digital agriculture technologies. The review further evaluates the constraints to adoption and identifies policy and institutional measures required to support sustainable livestock development under Afghanistan's socio-economic and agro-ecological conditions.

Methodology

This review adopts a narrative literature review approach to synthesize and interpret existing knowledge on livestock productivity, management practices, and technological innovations in animal production systems. A comprehensive literature search was conducted using major scientific databases, including Scopus, Web of Science, ScienceDirect, Google Scholar, and CAB Abstracts. In addition, reports and policy documents published by international organizations such as the Food and Agriculture Organization (FAO), the World Bank, and the Organisation for Economic Co-operation and Development (OECD) were consulted to provide broader institutional and policy perspectives.

The literature search focused on publications released between 2010 and 2025. Relevant studies were identified using combinations of keywords including "livestock productivity," "animal production systems," "livestock nutrition," "feeding management," "animal health," "disease control," "animal welfare," "housing systems," "genetic improvement," "livestock breeding," "precision livestock farming," "digital agriculture," "smart farming," and "Afghanistan livestock sector." Following the screening process, approximately 40 peer-reviewed articles and authenticated institutional reports were selected based on their relevance, scientific quality, and contribution to the review objectives.

The selected literature was analyzed and synthesized across six major thematic areas: (i) livestock feeding and nutritional management, (ii) housing systems and animal welfare, (iii) animal health and disease control, (iv) genetic improvement and breeding strategies, (v) precision livestock farming technologies, and (vi) digital agriculture applications. Due to the limited availability of empirical studies conducted in Afghanistan, evidence from comparable low- and middle-income countries was also examined. These findings were critically assessed and contextualized to reflect Afghanistan's socio-economic conditions, production systems, and agro-ecological characteristics.

Pakistan, Ethiopia, and Nepal were selected as comparator countries because they share several important characteristics with Afghanistan that are relevant to livestock production and rural development. These countries have large rural populations that depend heavily on agriculture and livestock for their livelihoods, predominantly smallholder-based farming systems, and significant reliance on mixed crop–livestock and pastoral production systems. In addition, they face similar challenges, including feed shortages, animal disease burdens, limited access to veterinary and extension services, weak market integration, and increasing vulnerability to climate change. Despite these constraints, all three countries have implemented various livestock development interventions, including improved breeding programs, community-based animal health services, and digital agricultural innovations. Therefore, comparing Afghanistan with Pakistan, Ethiopia, and Nepal provides valuable insights into practical and context-relevant strategies that could support sustainable improvements in livestock productivity under similar socio-economic and agro-ecological conditions.

Results

Livestock Production in Afghanistan

Livestock production in Afghanistan is largely dominated by extensive and semi-extensive systems that depend primarily on natural rangelands, seasonal mobility, and traditional grazing practices. Transhumant and pastoral production systems remain widespread, particularly among nomadic and semi-nomadic populations such as the Kuchi communities, for whom livestock constitutes the principal livelihood asset (FAO, 2019). These systems are typically characterized by low levels of external input use, limited mechanization, and minimal adoption of improved animal breeds, balanced rations, or commercially formulated feeds.

Although such traditional production systems are relatively well adapted to Afghanistan's harsh climatic conditions, fragile ecosystems, and chronic resource limitations, they are frequently associated with low levels of productivity at the animal level. Inadequate feed quantity and quality, persistent disease challenges, and suboptimal herd and health management practices collectively constrain growth rates, reproductive performance, and milk yields (World Bank, 2014). Moreover, increasing pressure on communal grazing lands, driven by rising livestock numbers, prolonged droughts, and weak rangeland governance, has led to widespread overgrazing and progressive rangeland degradation, further diminishing forage availability and adversely affecting livestock performance and system sustainability (Darnhofer et al., 2016).

The interaction between livestock production and ecosystems is complex and highly dependent on geographical conditions, resource availability, and management practices. Traditional livestock production systems are generally resource-based, relying on locally available feed resources with limited alternative uses, such as crop residues, natural rangelands, and marginal grazing lands unsuitable for crop cultivation (Steinfeld et al., 2006; Herrero et al., 2013; Thornton, 2010). In mixed farming systems, livestock and crop production are closely integrated, with livestock providing manure, draft power, and other inputs that contribute to soil fertility and agricultural productivity (Tarawali et al., 2011; Herrero et al., 2010).

Increasing global demand for livestock products has significantly altered the relationship between livestock production and natural resources. Modern intensive production systems are increasingly dependent on externally sourced feed inputs and have become less connected to local resource bases (FAO, 2018; Gerber et al., 2013). Simultaneously, competition for land, water, and biomass resources has intensified due to urbanization, industrial development, and the expansion of biofuel production, increasing the opportunity cost of resources previously available to livestock production (Searchinger et al., 2019; Steinfeld et al., 2006).

The geographical separation between intensive livestock operations and feed-producing areas often results in nutrient imbalances and the accumulation of manure and other waste products, creating environmental challenges such as water contamination and soil degradation (Gerber et al., 2013; FAO, 2018). In contrast, grazing and mixed farming systems tend to operate as more circular production systems in which crop residues and animal manure are recycled within the farm (Herrero et al., 2013). Furthermore, the livestock sector contributes substantially to greenhouse gas emissions, including methane and nitrous oxide, making it an important factor in climate change mitigation efforts (IPCC, 2022; Gerber et al., 2013). As livestock production continues to expand globally, sustainable production approaches will be required to increase productivity while reducing environmental impacts and conserving natural resources (Mottet et al., 2017; FAO, 2018).

Table-1: Comparative characteristics of livestock production systems in Afghanistan and selected developing countries

Characteristic	Afghanistan	Comparable developing countries (e.g., Pakistan, Ethiopia, Nepal)	References
Dominant production system	Extensive and semi-extensive; pastoral and agro-pastoral systems	Mixed crop–livestock, pastoral, and semi-intensive systems	FAO (2019); World Bank (2014)
Grazing and feeding practices	Heavy reliance on natural rangelands and seasonal transhumance; limited feed supplementation	Combination of grazing, crop residues, and supplementary feeding	FAO (2018); Thornton (2010)
Level of external inputs	Very low (limited use of concentrates, veterinary inputs, and improved housing)	Low to moderate, depending on region and market access	World Bank (2014); Klerkx et al. (2019)
Use of improved breeds	Minimal adoption of improved or crossbred animals; dominance of indigenous breeds	Increasing use of improved and crossbred animals in peri-urban areas	FAO (2018); Thornton & Herrero (2015)
Veterinary and extension services	Weak coverage, limited disease surveillance and extension outreach	Variable but generally stronger institutional support	FAO (2019); MAIL (2022)
Productivity per animal	Low milk yield, growth rate, and reproductive efficiency	Low to moderate productivity; higher than Afghanistan on average	World Bank (2014); FAO (2018)
Market integration	Poorly integrated markets; weak infrastructure and value chains	Better access to input and output markets	World Bank (2014); OECD (2020)
Environmental constraints	High exposure to drought, rangeland degradation, and water scarcity	Similar challenges, but often with better adaptation strategies	Darnhofer et al. (2016); Thornton & Herrero (2015)
Adoption of modern technologies	Very limited adoption of precision livestock farming and digital tools	Emerging adoption of digital and smart agriculture technologies	Berckmans (2017); Klerkx et al. (2019)

Improved Livestock Feeding and Management

Feeding and nutrition management is widely acknowledged as a primary determinant of livestock productivity, animal health, and system resilience, particularly within extensive and low-input production systems typical of many developing countries (Thornton, 2010; Garnsworthy et al., 2016). In Afghanistan, prevailing feeding practices are largely dependent on natural rangelands, seasonal grazing movements, and crop residues generated from cereal-based farming systems. These feed resources are generally characterized by low digestibility, insufficient crude protein levels, and imbalanced mineral profiles, leading to widespread nutritional deficiencies among livestock populations (FAO, 2018).

Pronounced seasonal variability in feed availability represents a major nutritional constraint across Afghan livestock systems. During winter periods and recurrent drought events, forage scarcity becomes severe, resulting in prolonged negative energy balance and deterioration of body condition in

animals. Empirical studies and development assessments have consistently linked such nutritional stress to reduced growth rates, depressed milk yields, extended calving intervals, compromised reproductive efficiency, and weakened immune responses, thereby increasing susceptibility to endemic and opportunistic diseases (FAO, 2018; World Bank, 2014).

Addressing these constraints requires the implementation of integrated feeding and feed management trategies that improve both feed quality and utilization efficiency. The formulation of nutritionally balanced rations tailored to species, age, and physiological status particularly during late gestation, early lactation, and growth phases has been shown to significantly enhance productivity outcomes under smallholder and pastoral conditions (Garnsworthy et al., 2016). Strategic supplementation with protein-rich feeds, energy sources, and mineral–vitamin premixes plays a critical role in correcting dietary deficiencies and improving milk production, fertility, and animal survival rates (FAO, 2018; Khan et al., 2015). Organic acids, particularly citric acid, have emerged as effective nutritional interventions to improve feed utilization and productivity in broiler chickens under Afghan farming conditions (Sahes et al., 2025).

In addition to ration-based interventions, the development of improved forage resources represents a key pathway for strengthening feed security and reducing pressure on degraded rangelands. The introduction of cultivated fodder crops, forage legumes, and improved pasture species particularly those adapted to drought-prone environments has demonstrated substantial potential to enhance feed availability and nutritional quality (Thornton, 2010; Darnhofer et al., 2016). Furthermore, forage conservation practices such as haymaking and silage production enable the storage of surplus biomass during periods of seasonal abundance, thereby mitigating feed shortages during winter and dry seasons and contributing to more stable livestock performance throughout the year (Thornton, 2010; FAO, 2018).

Overall, strengthening feeding and nutrition management through a combination of balanced ration formulation, targeted supplementation, forage development, and feed conservation constitutes a foundational strategy for improving livestock productivity and sustainability in Afghanistan. Nevertheless, the effective adoption of these interventions is contingent upon supportive extension services, farmer capacity building, and improved access to affordable feed inputs that are compatible with local agro-ecological and socio-economic conditions (World Bank, 2014; Klerkx et al., 2019). Many studies have concluded that phytogenic feed additives, such as cinnamon, oregano, thyme, ginger, peperment and moringa…, can enhance feed efficiency, carcass characteristics, productivity, disease, and antioxidant resistance in farm animals (Sahes et al., 2024; Nastoh et al., 2024; Nastoh et., 2025; Nastoh et al., 2026).

Among the feeding and nutrition interventions discussed, forage development, feed conservation practices, and strategic supplementation are likely to be the most feasible and impactful options for Afghanistan in the short to medium term. Given the country's heavy dependence on natural rangelands, recurrent droughts, and limited financial resources among smallholder farmers, the introduction of drought-tolerant forage crops, improved pasture management, haymaking, and silage production can significantly improve year-round feed availability at relatively low cost. Strategic supplementation using locally available feed resources and mineral mixtures also offers a practical approach to addressing major nutritional deficiencies. In contrast, the widespread adoption of precision feeding technologies and commercially formulated rations may be constrained by limited infrastructure, technical capacity, and economic resources. Therefore, priority should be given to scalable and locally adapted feed management interventions that can be readily implemented under Afghanistan’s existing production systems while gradually integrating more advanced nutritional technologies as institutional and market conditions improve.

Housing and Animal Walefare

Appropriate housing conditions and adherence to animal welfare principles are fundamental to safeguarding livestock health, optimizing productive performance, and ensuring sustainable production systems. In Afghanistan, livestock shelters are predominantly traditional in design and frequently lack essential features such as adequate ventilation, effective waste management, and sufficient insulation against extreme seasonal temperatures. These deficiencies contribute to elevated levels of thermal stress, poor hygiene, and increased exposure to infectious agents, thereby heightening disease incidence and negatively affecting animal performance (McManus et al., 2016; FAO, 2019).

The adoption of improved housing designs that provide sufficient floor space, effective air circulation, proper drainage, and hygienic resting areas has been shown to significantly enhance animal comfort and welfare outcomes. Enhanced welfare conditions reduce physiological and behavioral stress responses, improve feed intake and feed conversion efficiency, and support normal reproductive function, ultimately leading to higher productivity and improved animal longevity (Fraser, 2008; Caja et al., 2016). Moreover, welfare-oriented housing systems facilitate better disease prevention and management by enabling improved sanitation and biosecurity practices, which are particularly critical in low-input livestock systems (Caja et al., 2016; World Bank, 2014).

Animal welfare is widely recognized as a multidimensional concept encompassing both the physical and psychological well-being of animals. Achieving high welfare standards requires minimizing pain, stress, hunger, thirst, and other sources of discomfort while ensuring that animals can express normal biological functions and behaviors (Fraser, 2008; Mellor, 2016). Adequate nutrition and continuous access to clean water are fundamental components of animal welfare because they support health, physiological functioning, productivity, and overall well-being (Webster, 2016; Dawkins, 2023).

Nutritional deficiencies or imbalanced diets can impair growth, reproduction, immune competence, and metabolic functions, thereby negatively affecting animal welfare. Malnutrition occurs when the quantity or quality of nutrients supplied fails to meet the animal's physiological requirements. Conversely, well-balanced feeding programs contribute not only to productive performance but also to disease resistance and behavioral stability (FAO, 2023; Dawkins, 2023).

Feeding behavior provides valuable insights into animal welfare status. Animals must be able to access feed and water without excessive competition, stress, or restriction. In group-housed production systems, factors such as stocking density, feeder design, social hierarchy, and feeding management influence feeding patterns and resource access (Estevez et al., 2021; OIE, 2023). Changes in feed intake, feeding frequency, or feeding behavior may serve as early indicators of stress, disease, or welfare challenges and are increasingly used as welfare assessment tools in modern livestock systems (Mellor et al., 2020; Berckmans, 2017).

For all the above, it is argued that the disciplines of nutrition and animal behavior need to be integrated in order to more fully consider the implications of feeding behavior and nutrition on animal well-being.

Record-Keeping and Farm Management

Systematic record-keeping constitutes a core component of efficient livestock farm management, as it provides the empirical basis for planning, monitoring, and evaluating herd performance. However, within traditional livestock production systems in Afghanistan, the practice of maintaining structured farm records remains limited and largely informal. The absence of reliable records on key parameters such as breeding events, animal health interventions, feeding regimes, and production out-

puts constrains farmers' ability to assess productivity trends, identify management bottlenecks, and implement timely corrective actions (Hostiou, 2012; FAO, 2019).

Accurate and consistent farm records enable evidence-based decision-making by facilitating the monitoring of reproductive efficiency, disease incidence, feed utilization, and overall production performance. Such information is essential for improving herd organization, optimizing resource allocation, and enhancing economic efficiency, particularly in low-input and smallholder livestock systems (Hostiou, 2012).

Recent advances in digital agriculture have introduced novel opportunities to strengthen record-keeping and farm management through the use of mobile-based applications, digital logbooks, and integrated farm management software. When appropriately adapted to local contexts and supported by extension services and capacity-building initiatives, these digital tools can significantly improve data accuracy, accessibility, and timeliness, even among smallholder and pastoral livestock producers (Eastwood et al., 2017). Improved access to farm-level data through digital platforms has the potential to enhance decision-support processes, promote better management practices, and ultimately contribute to increased livestock productivity and sustainability in resource-constrained settings.

Table 2. Comparison between traditional and digital livestock farm management systems

Dimension	Traditional farm management	Digital farm management	References
Record-keeping method	Informal, memory-based, or paper records; often incomplete	Digital records using mobile apps, software, and cloud-based systems	Hostiou & Dedieu (2012); Eastwood et al. (2017)
Data accuracy and consistency	Low accuracy; prone to loss and human error	High accuracy with automated data entry and standardized formats	Eastwood et al. (2017)
Monitoring of animal performance	Limited and irregular monitoring	Continuous or real-time monitoring of health, reproduction, and production	Berckmans (2017); Eastwood et al. (2017)
Decision-making process	Experience-based and reactive	Data-driven and proactive decision-support	Hostiou & Dedieu (2012)
Labor efficiency	Labor-intensive with high time requirements	Reduced labor through automation and digital tools	Eastwood et al. (2017)
Disease and health management	Delayed detection of health problems	Early detection through alerts, trends, and predictive analytics	Berckmans (2017); Caja et al. (2016)
Reproductive management	Irregular breeding records and low reproductive efficiency	Improved breeding control through precise record tracking	Hostiou & Dedieu (2012); Eastwood et al. (2017)
Economic and financial analysis	Rarely conducted; limited cost tracking	Integrated cost–benefit analysis and financial planning	World Bank (2014); Eastwood et al. (2017)
Accessibility for smallholders	High (low cost, familiar practices)	Conditional; requires training, infrastructure, and technical support	Klerkx et al. (2019)
Scalability and long-term planning	Limited scalability	High potential for scaling and long-term strategic planning	Eastwood et al. (2017)

As illustrated in Table 2, digital farm management systems offer substantial advantages over traditional practices in terms of data accuracy, decision support, and productivity, although their successful adoption in smallholder contexts depends on adequate training and institutional support.

Modern Technologies for Enhancing Livestock Productivity

Precision Livestock Farming (PLF)

Precision Livestock Farming (PLF) encompasses the integration of advanced sensor-based technologies, automated monitoring systems, and data-driven analytical tools to enable continuous and objective assessment of livestock and their surrounding environments (Banhazi et al., 2012). Core PLF technologies include wearable and implantable sensors, imaging systems, acoustic sensors, and automated live-weight measurement devices, which collectively generate real-time data on animal health status, behavior patterns, physiological responses, and productive performance (Rutten et al., 2013).

By facilitating continuous monitoring at the individual-animal level, PLF systems enhance the early detection of health disorders, allow timely intervention before clinical symptoms become severe, and support more precise and efficient feeding and reproductive management strategies. Empirical evidence indicates that the application of PLF contributes to improvements in productivity, feed-use efficiency, reproductive performance, and overall animal welfare, while simultaneously reducing labor demands and management-related uncertainties (Berckmans, 2017; Neethirajan, 2020).

Although PLF technologies were initially developed and adopted within highly intensive livestock production systems in developed countries, recent technological advancements have led to the emergence of lower-cost, modular, and scalable solutions. These innovations hold considerable potential for adaptation within emerging livestock systems, including commercial and peri-urban farms in Afghanistan, provided that supportive infrastructure, technical training, and institutional frameworks are in place (FAO, 2021). Despite the potential benefits of Precision Livestock Farming technologies, their widespread implementation in Afghanistan faces significant challenges, including limited access to electricity and internet connectivity, inadequate technical expertise, high initial investment costs, and the predominance of smallholder and extensive livestock production systems. Therefore, the direct adoption of advanced PLF systems commonly used in developed countries may not be feasible in the short term.

A more practical approach would involve the gradual introduction of low-cost and user-friendly technologies, such as mobile phone–based record-keeping applications, digital animal identification systems, simple health-monitoring devices, and community-based advisory platforms. Pilot projects implemented through government agencies, universities, non-governmental organizations, and private-sector partnerships could help demonstrate the economic benefits of these technologies and build local technical capacity. As infrastructure, digital connectivity, and farmer awareness improve, more advanced PLF applications could be progressively integrated into commercial and peri-urban livestock production systems in Afghanistan.

Smart Agriculture and Digital Technologies

Smart agriculture involves the incorporation of information and communication technologies (ICT), artificial intelligence (AI), and Internet-of-Things (IoT) devices into agricultural production systems to enable more precise, efficient, and data-driven management (OECD, 2019). Within the livestock sector, these technologies facilitate automated feeding, water supply regulation, microclimate control in housing systems, and continuous monitoring of animal performance parameters (Silva et al., 2020).

Beyond on-farm automation, digital platforms can enhance access to critical support services, including veterinary advice, extension guidance, and market intelligence. In the context of Afghanistan, where mobile phone penetration is steadily increasing, the deployment of digital advisory services offers a promising mechanism to bridge information gaps, support evidence-based decision-making, and improve overall livestock management practices (Klerkx et al., 2019; FAO, 2021). Such innovations can be particularly transformative for smallholder and peri-urban producers, where traditional service delivery is often limited.

Genetic Improvement and Breeding Technologies

Genetic improvement represents a strategic, long-term approach for increasing livestock productivity, resilience, and adaptability to environmental stressors. Key interventions include the selection of superior animals, implementation of controlled mating schemes, and crossbreeding programs aimed at enhancing growth rates, milk production, reproductive efficiency, and disease resistance (Bishop & Woolliams, 2014).

In Afghanistan, formal breeding programs remain scarce, and uncontrolled mating practices are prevalent, limiting the genetic potential of national livestock populations. To address this challenge, community-based breeding programs, supported by basic record-keeping and extension services, have been proposed as a practical and scalable approach for genetic enhancement. Such programs can leverage local knowledge while gradually introducing improved breeding strategies to strengthen herd performance and productivity (FAO & World Bank, 2019; Thornton, 2010). Also, artificial insemination has demonstrated considerable potential in improving reproductive efficiency and genetic dissemination in poultry systems in Afghanistan (Sahes et al., 2024).

Table 3. Effects of Modern Technologies and Genetic Improvement Interventions on Livestock Productivity

Dimension	**Modern Technologies**	**Genetic Improvement & Breeding**	**References**
Objective	Real-time monitoring, automated management, precision feeding, and welfare improvement	Long-term enhancement of growth, milk yield, reproductive efficiency, and disease resistance	Berckmans (2017); Bishop & Woolliams (2014)
Core tools	Wearable sensors, cameras, microphones, automated weighing, IoT devices, AI platforms	Controlled mating, selection of superior animals, and crossbreeding programs	Rutten et al. (2013); FAO & World Bank (2019)
Data utilization	Continuous data collection, predictive analytics, decision-support systems	Performance and pedigree records to guide selection and breeding decisions	Eastwood et al. (2017); Hostiou & Dedieu (2012)
Time horizon for impact	Short- to medium-term; immediate improvements in management and productivity	Medium- to long-term; cumulative genetic gains over generations	Berckmans (2017); Bishop & Woolliams (2014)
Adoption context	Suitable for commercial, peri-urban, and progressively smallholder farms; depends on infrastructure and training	Community-based or structured breeding programs; feasible in smallholder and pastoral systems	FAO (2021); Thornton (2010)
Cost considerations	Initial investment can be high; scalable low-cost solutions emerging	Costs associated with record-keeping, controlled mating, and extension support; lower	FAO & World Bank (2019); Klerkx et al. (2019)

		technological requirements	
Benefits	Early disease detection, optimized feeding, improved welfare, labor efficiency, higher productivity	Genetic resilience, higher milk/meat yield, improved reproduction, disease resistance	Neethirajan (2020); Bishop & Woolliams (2014)
Limitations	Requires technical skills, reliable electricity/internet, and maintenance	Slow realization of benefits, risk of inbreeding if poorly managed, requires consistent record-keeping	Berckmans (2017); FAO & World Bank (2019)
Relevance to Afghanistan	Promising for commercial/peri-urban farms; adaptation needed for smallholders	High potential; community-based breeding can gradually improve national herd genetics	FAO (2021); Thornton (2010)

Table 3 provides a comparative overview of modern technological solutions and genetic improvement strategies for enhancing livestock productivity. While modern technologies offer rapid gains in management efficiency and welfare, genetic improvement programs provide sustainable long-term productivity enhancements, particularly when integrated with proper record-keeping and extension support. Both approaches can be adapted to the Afghan context with appropriate technical, infrastructural, and institutional support.

Animal Health and Disease Control Technologies

Animal health constraints constitute one of the most significant factors limiting livestock productivity in Afghanistan. The sector is particularly affected by several endemic and economically important diseases, including foot-and-mouth disease (FMD), peste des petits ruminants (PPR), brucellosis, anthrax, mastitis, parasitic infestations (internal and external parasites such as ticks and gastrointestinal worms), and Newcastle disease in poultry. These diseases are responsible for high morbidity, reduced growth rates, decreased milk and meat production, reproductive failures, and significant mortality losses across livestock systems in the country (FAO, 2018; MAIL, 2022).

The adoption of modern animal health technologies offers effective solutions to mitigate these constraints. Structured vaccination campaigns targeting priority diseases such as FMD, PPR, brucellosis, and Newcastle disease can significantly reduce outbreak frequency and severity. Similarly, regular deworming programs and parasite control strategies improve weight gain, milk yield, and overall animal condition. Biosecurity measures, including controlled animal movement, quarantine practices, and improved farm hygiene, are critical in limiting disease transmission, particularly in smallholder and peri-urban systems.

Furthermore, the integration of sensor-based health monitoring systems—including wearable devices, automated temperature and activity trackers, and early-warning alert systems—enables continuous detection of early clinical signs such as fever, reduced feed intake, lameness, and abnormal behavior, allowing for timely veterinary intervention before diseases become severe or widespread (Steeneveld et al., 2015; Berckmans, 2017).

These technologies not only enhance productivity by reducing disease-related losses but also improve animal welfare, reproductive performance, and feed efficiency. However, in Afghanistan, their effective implementation requires adaptation to local production systems, strengthening of veterinary infrastructure, improved vaccine supply chains, and targeted capacity-building for farmers and animal health workers (FAO, 2018; WOAH, 2021).

Constraints to Technology Adoption

Adoption of modern livestock technologies in Afghanistan faces multiple interrelated constraints that limit their effectiveness and widespread uptake. These challenges can be broadly categorized into economic, infrastructural, human capacity, and institutional factors. Understanding these barriers is critical for designing interventions that are both feasible and sustainable within the Afghan context (FAO, 2021; Klerkx et al., 2019).

Emerging technologies are playing an increasingly important role in improving animal health management and disease control. Advances in genomics, proteomics, diagnostics, and vaccine development have enhanced the ability to detect, prevent, and manage livestock diseases more effectively than traditional approaches. These innovations contribute to reduced disease incidence, improved productivity, and enhanced food security in livestock production systems (FAO, 2023; WOAH, 2024).

Despite these advances, access to animal health technologies remains limited in many developing countries due to financial constraints, weak veterinary infrastructure, and inadequate private-sector investment. Smallholder livestock producers often face difficulties obtaining quality vaccines, diagnostic services, and veterinary pharmaceuticals, reducing the effectiveness of disease prevention and control programs (FAO, 2023).

In Afghanistan, livestock diseases continue to constrain productivity and rural livelihoods. Strengthening veterinary services, improving disease surveillance systems, expanding vaccination programs, and facilitating access to affordable animal-health technologies are essential for improving livestock performance. Regional cooperation in the control of transboundary animal diseases, combined with targeted public investment and international support, can further enhance the resilience and sustainability of the livestock sector (FAO, 2022; 2021; WOAH, 2024).

Economic and Financial Barriers

High upfront costs associated with precision livestock farming tools, digital platforms, improved housing systems, and advanced breeding technologies represent a significant obstacle to adoption. Most Afghan livestock producers operate smallholder or semi-subsistence systems with minimal capital reserves and limited access to formal financial services, including credit, microfinance, insurance, and government subsidies. Consequently, even when technologies are technically feasible, farmers may be unable to afford initial investments or ongoing maintenance costs (World Bank, 2014; FAO, 2021). This economic limitation is compounded by the fact that short-term productivity gains are often modest, while benefits from long-term interventions such as genetic improvement programs or PLF systems may take several production cycles to materialize. Without financial support mechanisms, adoption remains constrained, particularly for the most vulnerable households in rural and remote regions.

Infrastructure and Energy Limitations

Adequate infrastructure and reliable energy supply are essential prerequisites for deploying digital and automated livestock technologies. In Afghanistan, however, electricity access is often intermittent, internet connectivity is limited in rural and mountainous regions, and transport networks remain underdeveloped (OECD, 2019; FAO, 2021). These infrastructural deficiencies hinder the use of digital advisory services, automated feeding systems, climate-controlled housing, and sensor-based monitoring tools. Moreover, poor transport infrastructure restricts timely access to veterinary inputs, improved feed, and maintenance services, reducing the feasibility of technology adoption even in peri-urban areas. As a result, the benefits of precision livestock farming and smart agriculture remain

concentrated in areas with better infrastructure, leaving smallholder and remote farmers underserved (Klerkx et al., 2019; Eastwood et al., 2017; FAO, 2022;).

Human Capacity and Institutional Challenges

Human capital limitations and institutional weaknesses constitute additional critical barriers. Low literacy and numeracy levels, coupled with minimal technical training, restrict farmers' capacity to understand, operate, and maintain modern technologies effectively (FAO, 2021). Extension services, which are central to transferring knowledge and building skills, remain weak, fragmented, and under-resourced. Furthermore, coordination among government agencies, research institutions, and development partners is often insufficient, limiting the delivery of integrated support packages such as training, maintenance, and access to inputs (Klerkx et al., 2019). Strengthening institutional capacity, including policy support, advisory frameworks, and farmer training programs is therefore essential to ensure the sustainable adoption of modern livestock technologies and to maximize their impact on productivity and animal welfare.

Sociocultural and Behavioral Barriers

In addition to economic, infrastructural, and institutional constraints, sociocultural and behavioral factors can influence technology uptake. Traditional knowledge, customary herd management practices, risk aversion, and limited exposure to modern methods may reduce farmers' willingness to adopt new interventions. Community engagement, participatory training, and demonstration projects have been shown to improve acceptance and uptake of innovations, particularly when technologies are adapted to local socio-economic and agro-ecological conditions (Thornton, 2010; FAO, 2018).

Discussion

The synthesis of available literature clearly demonstrates that enhancing livestock productivity in Afghanistan necessitates a holistic and integrated approach. Isolated interventions, whether through management improvements or technological adoption alone, are unlikely to achieve substantial gains in productivity, animal welfare, or sustainability. Rather, combining improved feeding and nutrition strategies, housing and welfare enhancements, systematic record-keeping, disease control, and targeted genetic improvement with context-specific modern technologies—such as precision livestock farming (PLF) and digital advisory systems—offers the greatest potential for impact (Berckmans, 2017; FAO, 2021).

Evidence from similar developing countries suggests that the direct transplantation of advanced livestock technologies from developed nations may not be feasible due to economic, infrastructural, and human capacity constraints (Thornton, 2010; Rose et al., 2021). However, appropriately adapted and scaled solutions can overcome these limitations. For example, modular PLF systems and low-cost sensor technologies can be deployed in peri-urban or semi-commercial farms, while mobile-based digital platforms can extend advisory services to remote smallholders, enhancing disease monitoring, feeding practices, and market access (Eastwood et al., 2017; Klerkx et al., 2019). Similarly, community-based breeding programs combined with simple record-keeping systems provide a pragmatic pathway for gradual genetic improvement without requiring high initial investments or sophisticated infrastructure (FAO & World Bank, 2019).

Public-private partnerships (PPPs) and pilot demonstration projects emerge as essential mechanisms for promoting technology adoption. PPPs can mobilize financial resources, technical expertise, and logistics to implement scalable solutions, while pilot projects allow farmers to observe tangible benefits, reduce perceived risks, and build trust in new technologies (OECD, 2019; Berckmans,

2017). Additionally, capacity-building initiatives targeting farmers, extension workers, and local veterinary personnel are indispensable for ensuring proper operation, maintenance, and integration of modern technologies with traditional production systems (FAO, 2021).

Policy frameworks play a pivotal role in facilitating the adoption of improved practices and technologies. Access to affordable credit, subsidies for technology uptake, investments in rural infrastructure (electricity, internet, transport), and programs to strengthen extension and advisory services collectively create an enabling environment for sustainable livestock development (World Bank, 2014; OECD, 2019). Importantly, interventions must be designed to consider the socio-economic realities, cultural practices, and agro-ecological conditions specific to Afghanistan to ensure long-term sustainability and widespread adoption (Thornton & Herrero, 2015).

Furthermore, integration across thematic areas nutrition, housing, health, genetics, and technology is crucial to achieve synergistic effects. For instance, improved feeding strategies without adequate housing or disease management may fail to translate into productivity gains, while genetic improvement efforts without reliable record-keeping or health interventions may be ineffective. Therefore, a systems-level approach, which simultaneously addresses economic, infrastructural, human, and institutional constraints, is required to maximize livestock productivity, resilience, and contribution to rural livelihoods (FAO, 2018; Rose et al., 2021).

Finally, climate change, rangeland degradation, and water scarcity must be considered as cross-cutting factors influencing the adoption and effectiveness of interventions. Technologies and management practices that enhance resource efficiency, such as water-saving feeding systems or drought-tolerant fodder crops, not only improve productivity but also contribute to environmental sustainability and long-term resilience of Afghan livestock systems (Thornton & Herrero, 2015; FAO, 2018).

Conclusion

This review indicates that improving livestock productivity in Afghanistan requires a combination of practical management interventions and carefully selected technological innovations adapted to local conditions. Among the approaches reviewed, improved feeding and nutritional management, strengthened animal health services, genetic improvement through selective breeding and artificial insemination, and enhanced housing and welfare practices appear to offer the most immediate and cost-effective opportunities for increasing livestock productivity.

Although advanced technologies such as precision livestock farming, sensor-based monitoring, and digital advisory systems have demonstrated significant benefits in many countries, their widespread adoption in Afghanistan is currently constrained by limited infrastructure, unreliable electricity supply, weak internet connectivity, and insufficient technical capacity. Therefore, the short-term priority should be the expansion of basic veterinary services, farmer training programs, improved feed resources, and accessible breeding technologies.

In the longer term, gradual investment in rural infrastructure, digital connectivity, and agricultural extension systems can create the conditions necessary for adopting more advanced livestock technologies. A phased and context-specific approach that combines proven management practices with appropriate technological innovations is likely to provide the greatest contribution to livestock productivity, food security, and rural livelihoods in Afghanistan.

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