



CHAPTER 9

Emerging Technologies for Resilient and Competitive Livestock Systems

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Introduction

Livestock production systems constitute a fundamental pillar for livelihoods, food security, and the preservation of sociocultural structures across Africa. Nevertheless, these systems are subject to multifaceted pressures arising from ecological, economic, and institutional constraints. Extreme shocks related to climate change, animal diseases, volatile markets, and conflicts result in losses and damages, exacerbating livelihood vulnerability (Wane et al. 2023). These risks deter both domestic and foreign investment in the livestock sector (ILRI 2024). Traditionally, pastoral and agropastoral communities have developed coping strategies to mitigate these risks, including herd mobility, livelihood diversification, and intertemporal risk management practices (Kerven 1992; Fadiga 2013; Wane et al. 2023). However, the effectiveness of these mechanisms is increasingly constrained due to intensifying and more frequent perturbations, the growing human population, and rising demand for animal-source foods.

Addressing these evolving challenges requires a transformative approach that aims to enhance the productivity and resilience of African livestock systems and consolidate their contribution to national economies (Wane et al. 2020; Wong 2023). In this context, emergent technologies are catalyzing innovation within the sector. Technological advancements in genetics, animal nutrition, animal health, environmental management, and derisking livelihoods present significant opportunities to mitigate production risks, enhance efficiency, and improve market access. This chapter systematically examines these technological interventions by functional category, providing an integrative analysis with case-study illustrations of the impacts of emerging technologies across African livestock systems.

Categories of Emerging Technologies in Livestock Systems

Emerging technologies within African livestock production systems represent a diverse array of innovations aimed at improving productivity, environmental sustainability, and system resilience. These technologies are described in this section and are broadly categorized into:

- Genetic improvement methodologies, such as those related to artificial insemination and embryo transfer.
- Advanced nutritional interventions, including drought-tolerant forage cultivars and novel protein sources, like black soldier fly larvae.
- Digital innovations encompassing mobile extension advisory services and internet of things (IoT)-enabled herd, rangeland conditions, and market monitoring systems.
- Complementary climate-smart practices, including animal dietary strategies designed to reduce enteric methane emissions and rotational grazing regimes.
- Risk management mechanisms, including index-based insurance schemes.
- Animal health innovations, such as thermostable vaccines.
- Community-based governance frameworks that can facilitate equitable access to livestock resources and promote their sustainable use.

To illustrate the potential of these technological approaches for transforming rural livelihoods and enhancing the overall resilience of livestock systems across Africa, empirical case studies drawn from diverse African contexts are presented for each. In addition, we consider how these livestock innovations might improve rural livelihoods by creating meaningful economic opportunities for women and youth.

Genetic improvement technologies

Genetic improvement of livestock represents a critical lever for advancing agricultural development and food system resilience in Africa. Enhancing the genetic potential of livestock populations is associated with improved productivity, greater resistance to infectious and parasitic diseases, and increased resilience to climatic variability, thus consolidating the already important role of livestock farming in African economies. For example, FAO (2019) and Marshall et al. (2019) have demonstrated that crossbred dairy cows in the tropics can produce between 40 and 80 percent more milk than indigenous breeds.

Today, a range of new technologies is helping to accelerate genetic progress in livestock, making herds healthier, more productive, and better adapted to local conditions across Africa. One of the most widely used tools is artificial insemination,

especially in dairy systems. For smallholder farmers, artificial insemination brings several important benefits. This includes giving them access to the semen from top-quality bulls for breeding, even if they cannot afford to keep such animals themselves. Farmers can also choose sires with traits that improve herd performance—for example, with enhanced milk yield and fertility or improved overall fitness. There are promising signs that these innovations are working.

- In East Africa, dairy initiatives in Kenya, Ethiopia, and Rwanda have demonstrated that combining artificial insemination with effective farmer support services leads to tangible progress, with cows producing more milk and their reproductive rates improving.

BOX 9.1—BOOSTING LIVESTOCK GENETICS IN NAMIBIA

Between 2007 and 2014, Namibia’s government ran the Bull Scheme program to help communal farmers improve their herds. The program distributed breeding animals to farmers, including bulls, goats, and sheep. Livestock numbers increased by 131 percent for cattle, 147 percent for sheep, and 67 percent for goats. In parallel, livestock commercialization increased, with a boost to farmer incomes. Farmers sold 43 percent more cattle than they did before the program started and income increased by 53 percent, especially for those who received bulls.

However, keeping these improvements going has been tough. After five years, fewer than half the bulls were still with the farmers—some died, while others were sold or culled. Livestock mortality was also high for small ruminants. The genetic improvement efforts were not accompanied by the adoption and consistent use of good livestock care practices or proper record keeping. Other challenges included limited feed, difficulties in accessing grazing lands, and a lack of training and support.

In short, while Namibia’s Bull Scheme helped improve livestock herds, increase herd sizes, and raise the incomes of livestock farmers, its long-term success will depend on improving animal care, providing stronger training, and expanding access to livestock resources.

Source: Marius et al. (2022).

- In Southern Africa, challenges continue to be mixed with success in efforts to improve traditional livestock systems (Box 9.1). However, embryo transfer in South Africa and Namibia is starting to impact the quality of livestock herds. Although it requires more resources and technical skills than artificial insemination, embryo transfer offers a way to quickly increase the number of cows with the most desired traits. Newer tools related to genomic selection are also helping. By identifying genes related to heat tolerance, disease resistance, or high milk production, researchers can select the best animals for breeding. Doing so is especially important in climates where traditional methods of choosing the best breeds are not robust.
- Northern Africa is also experiencing success. Tunisia’s Dairy Genetic Improvement Program is a notable example (Box 9.2). By carefully tracking herd performance, using artificial insemination with high-producing imported breeds, and encouraging strong collaboration among various organizations, Tunisian farmers have managed to boost milk yields, even in dry areas. The Tunisian experience demonstrates how good leadership, training, and teamwork can pay off in strengthened livestock systems.
- In West Africa, similar efforts are underway. Senegal, Mali, and Nigeria have been working to improve their local cattle breeds, like the N’Dama and White Fulani. Senegal’s “Projet de Développement de l’Élevage” has boosted milk production by combining artificial insemination with crossbreeding from international dairy breeds. Meanwhile, Nigeria is crossbreeding its Bunaji cattle with Friesians. However, challenges remain. Livestock infrastructure, the quality of farmer training, and the maintenance of accurate animal records all need improvement.

Africa’s local cattle, including the Sanga, Boran, and N’Dama, have developed unique strengths over generations. They cope well with endemic diseases, heat, and irregular feeding. When crossbreeding with imported breeds, care must be taken to balance productivity with these valuable local traits, thereby avoiding the loss of what makes these breeds special and well-adapted for their environment.

Despite recent progress, many barriers still slow down the adoption of these advanced breeding techniques. There is a lack of livestock infrastructure to support artificial insemination and embryo transfer activities; access to veterinary and educational services is often limited; and reliable systems for tracking animal performance are still scarce. Finally, ongoing disease threats and the challenges of

BOX 9.2—IMPROVING DAIRY CATTLE IN TUNISIA

In Tunisia, efforts to improve Holstein dairy cattle face several major challenges. Currently, breeding is poorly coordinated and mostly depends on the use of artificial insemination using imported bull semen. However, these imported genetics do not always perform well because the local environment influences how their traits manifest. Moreover, studies show that genetics has only a moderate role in milk production and a much smaller impact on cow longevity or fertility. In addition, health problems, including udder infections and lameness, cause between 15 and 22 percent of cows to be removed early from the herd, typically after just 3 or 4 years of production. Health records also are not kept systematically, making it difficult to breed cows for better health. To address this, Tunisia's livestock agency continues to promote artificial insemination for dairy cows and also provides veterinary care and support services to small farmers. As a result, milk production increased by 18 percent between 2016 and 2021.

Further efforts target the utilization of DNA technology to accelerate genetic improvements. Initially, the focus will be on selecting animals with specific genes linked to better milk production and health, but eventually, advanced genetic tools will be used to analyze a cow's entire genome. These techniques could boost the accuracy of breeding decisions, improve cow health and productivity, and help cows live longer, even in Tunisia's tough farming conditions.

Source: Sdiri et al. (2023), Ben Jemaa et al. (2018).

climate change make it even tougher for these genetic gains to deliver their full promise in improved livestock productivity.

Feed innovation and forage systems

Livestock plays a crucial role in Africa's food security, rural livelihoods, and economic growth. However, across the continent, most livestock keepers face serious challenges accessing good-quality feed and forage for their animals. This problem is exacerbated by changing weather patterns, land degradation, and

inadequate infrastructure, all of which limit livestock productivity. Finding new and better ways to feed animals is essential. Several promising solutions exist and could help address feed constraints in diverse regions across the continent.

- In West Africa, most livestock production is pastoral or agropastoral, with herders moving seasonally to find suitable grazing areas. During the dry season, feed shortages are severe, so innovators focus on improving feed reserves for these tough months—including improving pastures by planting improved forage species (Box 9.3), employing better ways to store crop residues, and developing systems for community management of rangelands.

BOX 9.3—BRACHIARIA GRASS SEED INNOVATION IN MALI

Brachiaria (palisade grass) cultivation has shown significant benefits for livestock productivity. The main results are related to a 15 to 40 percent increase in milk yield and weight gains of up to 50 percent. Its higher biomass yield and nutritional quality compared to traditional grasses, like Napier and Rhodes, make it a preferred forage for farmers, extension workers, and researchers. In the Sikasso region in Mali, multistakeholder partnerships between research institutions, non-governmental organizations, and local farmer cooperatives contributed to the establishment of a local seed production enterprise for *Brachiaria*. The forage's strong drought tolerance and high biomass output match well with Sahelian agroecological conditions. Between 2019 and 2022, over 200 hectares were cultivated, resulting in a reported 45 percent reduction in dry-season feed shortages and an improvement in livestock feed security in the area.

Source: Sow et al. (2024).

Farmers are also encouraged to grow dual-purpose crops, such as cowpea and sorghum, which provide both grain for people and high-quality fodder for animals.

- In Central Africa, countries like Cameroon and the Democratic Republic of Congo face heavy rainfall variation and limited options for producing

sufficient quantities of high-quality forage. One promising approach is silvo-pastoral systems, where trees that produce forage are grown alongside crops and livestock. Such farming systems make farms more resilient. However, poor infrastructure and limited access to markets make it difficult to bring such solutions to scale.

- In Eastern Africa, particularly Ethiopia and Kenya, the livestock sector includes both dryland pastoralist systems and mixed farms in the highlands. Farmers widely use forage crops, particularly various species of *Brachiaria*, Napier grasses, or forage legumes. Storing forage as hay or silage and carefully balancing animal diets with ration formulation tools—including Rumen8 (Rumen8 Nutrition 2025) and On-farm Feed Advisor (ILRI 2025)—are also becoming more common with the growing support of research and extension services. New feed sources are also being researched and piloted among livestock farmers. Among the efforts capturing considerable attention are those making use of black soldier fly as a protein source for livestock feed (Box 9.4).
- In Southern Africa, there have been advances in forage seed distribution, commercial fodder production, and private-sector involvement. Focus areas include breeding drought-tolerant forage plants and making better use of crop residues, such as maize stalks and groundnut haulms, to keep feed supplies steady despite irregular rainfall.
- In Northern Africa, arid regions struggle with water scarcity and degraded grazing lands. Livestock production in the region is mostly sedentary. Innovations focus on growing green forage hydroponically, supplementing feed with byproducts from agriculture and industry, and managing grazing lands better to keep forage available and nutritious.

Digital and mobile technologies

Digital technology is steadily changing the way livestock farming works across Africa. Mobile apps, remote sensing, artificial intelligence (AI), and blockchain are enhancing animal health monitoring and disease tracking, ultimately improving feed management and product traceability. These digital solutions boost productivity and enable small-scale farmers and pastoralists to engage in

BOX 9.4—BLACK SOLDIER FLY PROTEIN INNOVATION IN KENYA

The black soldier fly (BSF) industry is growing quickly in East Africa, especially in Kenya, where there are around 1,200 active producers. Most are located in Central and Western Kenya, where demand for affordable animal feed protein and organic fertilizer and awareness of BSF farming are quite strong. These producers range from small-scale farmers who mix BSF farming with their crop and livestock activities to larger commercial businesses that specialize in the sale of BSF eggs, larvae, protein meal, and frass (a natural fertilizer) in large quantities. BSF larvae offer a high-quality and affordable alternative to traditional feed ingredients, mainly replacing fish and soybean meal. With a protein content between 35 and 55 percent and beneficial fats, BSF larvae help animals, including pigs, poultry, and fish, grow faster and healthier. Because they are easy to digest and cost 15 to 30 percent less than standard feed options, BSF products are popular with both small farmers and commercial feed producers. Many smallholders benefit doubly by feeding larvae to their animals and using the leftover frass as fertilizer for their crops.

In Kenya, annual sales of BSF products are around US\$3 million, with most from two major producers. Using BSF protein in animal feeds helps farmers produce more meat, milk, and eggs, boosting local food security. Doing so also reduces dependence on expensive imported ingredients, helping to keep feed prices stable. The BSF sector still faces challenges—a lack of standards and regulations, informal business practices, limited advanced training, and inconsistent product quality. However, the benefits of lower feed costs and increased supply are encouraging more farmers to produce BSF. With adequate investment and support, BSF farming in Kenya can help strengthen the sustainability and resilience of local animal feed systems.

Sources: FAO (2023).

livestock supply chains more profitably. However, the rate and extent of adoption of these technologies vary significantly across Africa, depending on differences in internet access, government support, and people's comfort level with digital tools.

- In Eastern Africa, countries like Kenya, Ethiopia, and Uganda are leading the way. Kenya's vibrant digital technology scene has given rise to platforms like iCow and Farmers Pride, which provide farmers with advice, weather updates, and veterinary help right on their phones (Box 9.5). Ethiopia uses big data for smarter feed planning and disease forecasting,

BOX 9.5—iCOW PLATFORM IN KENYA

Traditional extension services often struggle with limited reach, high costs, and information that is not tailored to farmers' needs. The iCow digital platform helps to overcome these challenges by using technology to provide advice to smallholder livestock farmers across Kenya. iCow uses simple SMS messages to share timely tips and information about animal health, nutrition, disease control, breeding, and record keeping. It includes tools like a livestock calendar, a library of farming knowledge, and contacts for animal health experts, all accessible on basic mobile phones, making it easy for farmers to use even in remote areas. iCow now has an estimated 150,000 users.

Impact evaluations have shown that users of iCow adopted better animal care practices, which resulted in a 13 percent improvement in milk yields, a 29 percent rise in income from milk sales, and a 22 percent increase in household income. Poultry farmers reported even bigger gains, with profits increasing between 23 and 50 percent, often breaking even within 6 to 10 months of operation of their poultry business. In pilot areas, 8 percent of farmers started using BSF larvae-based livestock feeds, with ongoing use strongly linked to good training and access to credit.

Even though challenges like feed shortages and livestock diseases still exist, the information farmers obtain through iCow helps them to better respond to production and market shocks and improve the hygiene, feeding, and health of their animals. iCow shows the importance of investing in rural infrastructure and building strong public-private partnerships to lift rural communities out of poverty and drive sustainable agricultural change.

Sources: Chaix-Bar et al. (2023); Marwa et al. (2024).

BOX 9.6—CROWDSOURCING INFORMATION FOR CLIMATE RESILIENCE IN KENYA AND ETHIOPIA

The KAZNET platform, developed by the International Livestock Research Institute (ILRI), leverages citizen science and crowdsourcing to provide information critical for managing drought and food insecurity in the dry-lands of Kenya and Ethiopia. Designed to gather weekly, ground-truthed data, KAZNET operates through local contributors who collect information from livestock markets, rangeland transects, and households. Across the two countries, it monitors 44 livestock markets, 180 transects, and 552 households in areas where traditional survey methods are often impractical due to remoteness, insecurity, or lack of infrastructure.

The data collected is integrated with information from remote sensing e.g., Normalized Difference Vegetation Index (NDVI), and disseminated through early warning dashboards and digital platforms to inform interventions and market strategies. Clear pathways have been revealed in the data to link forage availability to food security. For example, a 10 percent improvement in forage condition correlates with an 11 percentage point reduction in household food insecurity, an 8 percent decrease in the duration of food deficits, and a 23 percent increase in daily milk production. Impact evaluations showed that individuals in the KAZNET initiative on average had a 15 percentage points higher probability of using crowdsourced information, increased their social learning by 27 percent, had a higher likelihood of adopting improved livestock management practices, chose more profitable selling markets for their goats and sheep, and experienced a 55 percent increase in livestock income.

KAZNET stakeholders recommend embedding KAZNET into national early warning systems, national livestock strategies, and climate adaptation initiatives. In addition, further collaboration with private digital agricultural advisory platforms and the use of KAZNET data to inform index-based livestock insurance programs will extend its ability to foster resilience, improve food security outcomes, and reduce vulnerability to climate shocks in Eastern Africa.

Source: Shikuku et al. (2024a), Shikuku et al. (2024b), Shikuku (2024), Shikuku et al. (2025).

helping dairy farmers and mixed farms produce more. Mobile tools, like KAZNET in northern Kenya and southern Ethiopia, are helping pastoralists track their herds and get early warnings about droughts, combining digital technologies with local knowledge to save their animals and build resilience. (Box 9.6). That said, many pilot projects lose momentum after a few years, often due to funding issues and poor integration with existing support systems.

- In Southern Africa, South Africa, Namibia, and Zambia are embracing precision livestock farming. Farmers obtain real-time insights into animal health, behavior, and the environment through technologies like radio frequency identification (RFID) tags, GPS collars, and other remote sensors. Zambia and Zimbabwe use digital platforms to promote climate-smart grazing and extend veterinary services to hard-to-reach areas. Smart feeding technologies and mobile financial services are also transforming commercial livestock businesses.
- West Africa is also witnessing rapid growth in digital livestock tools, especially in Nigeria, Ghana, and Senegal. Nigeria's Livestock247 and ThriveAgric platforms help farmers access finance, veterinary care, and new markets (Imonikhe 2025). Ghana and Senegal are deploying digital traceability systems designed for export markets. In the Sahel region, new initiatives aim to bring migrating herders into the digital fold by registering livestock and mapping grazing areas, although challenges remain due to poor infrastructure and low digital skills.
- Central Africa is lagging in the adoption of digital livestock technologies, largely due to poor infrastructure, spotty internet coverage, and political instability. Countries like Cameroon and the Democratic Republic of Congo rely on donor-funded pilot projects for mobile veterinary care, community disease tracking, and digital herd records. However, expanding these projects into remote and forested areas without reliable mobile networks or electricity is difficult. To bridge this gap, radio-based extension services combined with mobile feedback systems are being explored to reach farmers in remote communities.
- In North Africa, better infrastructure enables the use of advanced digital tools. Morocco, Tunisia, and Egypt are employing blockchain systems for traceability along meat and dairy value chains, using drones to monitor

BOX 9.7—INTERNET OF THINGS (IOT)-ENABLED LIVESTOCK HEALTH MONITORING IN MOROCCO

In Morocco, a smart livestock health monitoring system utilizes internet of things (IoT) technologies to closely monitor the well-being of animals. Tiny sensors track critical signs on the health of the animal, like heart rate and body temperature, while wireless communication and GPS enable farmers to monitor both their animal's location and health in real-time. All the data is sent to a cloud-based platform that farmers or veterinarians can access remotely, making it easier to manage herd health from anywhere. This system quickly identifies any unusual changes in an animal's vital signs, enabling farmers to intervene early before problems escalate. Because it uses stable, low-power technology, the technology can run for long periods without interruption. By automating health checks and sending alerts, work pressures are reduced for farmers, animal welfare is improved, and resources are managed more efficiently.

Future plans include adding more health measurements, enhancing sensor accuracy, and utilizing smart analytics to predict health issues and tailor care. This example from Morocco is just one of a broader wave of digital livestock innovations across Africa that combine technology with social and economic factors to enhance farming livelihoods and animal health on the continent.

Source: Shnain et al. (2025).

grazing lands, and leveraging artificial intelligence to optimize feed and water use. In Morocco, a pilot effort is underway on a real-time livestock health monitoring system that uses heart rate and temperature sensors on the animals and sensors recording environmental conditions in an Internet-of-Things system to gain insights on animal health and behavior that enables the early detection of problems like infections, diseases, or injuries (Box 9.7). Smart irrigation systems are also being developed for growing forage, while mobile veterinary services are being tailored to respond to animal health challenges in dry regions.

Despite this technical progress and the positive impacts of digital technologies on livestock keepers' livelihoods, challenges still exist. Many farmers lack digital skills, and women and young people are often excluded from these technology-enabled services. Rural digital infrastructure remains inadequate, and there has only been limited penetration of smartphones in livestock farming communities. Different digital systems do not always integrate well, and high costs make some technologies inaccessible. Gaps in both livestock and digital technology policies also hinder progress. Still, the expansion of mobile networks, active technology communities, and regional cooperation through groups like the African Union's InterAfrican Bureau for Animal Resources (AU-IBAR) and the Economic Community of West African States (ECOWAS) is fostering a more supportive environment for digital growth in Africa's livestock sector.

Innovative approaches have been suggested to address some of the constraints. Shikuku et al. (2025) advocate combining digital innovation and social learning to address the limited penetration of smartphones in remote pastoralist areas of Kenya. Use of interactive voice recording is another potential approach to addressing the barriers to adoption. Nonetheless, the barriers to adoption should be carefully assessed when developing strategies to scale up the use of digital and mobile technologies in livestock value chains across Africa.

Climate-smart and low-emission technologies

Livestock farming in Africa plays a complicated role in climate change because it both affects the environment and is highly sensitive to weather shifts. Because of this, it is crucial to introduce technologies that can reduce greenhouse gas emissions, especially from ruminant livestock, while also helping farmers adapt to unpredictable climate patterns. The right climate-smart, low-emission solutions need to be customized to fit the diverse environmental and social needs across different African regions. This tailored approach can reshape livestock farming into a more sustainable, resilient, and productive endeavor that meets both climate mitigation and adaptation goals.

- In East Africa, the focus has been on tackling methane emissions from ruminants, mainly through smarter feeding strategies, and creating circular systems that recycle nutrients and capture waste (Box 9.8). Countries like Ethiopia and Uganda have adopted climate-friendly feeding practices that make better use of nutrients and lower methane released during digestion.

BOX 9.8—LOW-METHANE FEEDING TRIALS IN ETHIOPIA

In Ethiopia, researchers from the International Livestock Research Institute (ILRI) and the ILRI-Mazingira Centre have been conducting controlled feeding trials to reduce greenhouse gas emissions from cattle while enhancing their growth. They tested the use of nitrate supplements in cattle diets and feeding cattle straw treated with urea. Both methods resulted in approximately a 30 percent reduction in methane emissions, the gas produced by cattle during digestion, and helped the animals gain an additional 0.2 kilograms in body weight per day. These improvements come from feeding the cattle more efficiently. Nitrate works by providing an alternative pathway in the animal's stomach, which reduces methane production, while treating straw with urea makes this low-quality feed easier to digest and richer in protein. As a result, the animals convert the feed into body weight more effectively.

These practices are affordable, easy to put into action, and can be scaled up widely. For small-scale farmers in Ethiopia, these feed innovations offer a practical way to lower the environmental footprint of their animals without sacrificing productivity. Improved climate resilience and food security across the country's livestock sector offers a win-win for farmers and the environment.

Source: Mazingira Centre Trials (2023-2025).

This includes adding supplements to feed and planting special forage species that naturally curb methane production. These steps help reduce livestock's carbon footprint while keeping animals healthy and productive, even when weather conditions are unpredictable.

- In Southern Africa, efforts are focused on managing grazing and water more sustainably in livestock production. In South Africa and Botswana, farmers use water-saving technologies and better pasture management to make the most of scarce resources. These innovations boost animal productivity, especially in dry, semi-arid areas, by easing drought effects and preventing

soil degradation, which in turn makes livestock systems more resilient in the face of climate stress.

- In the Sahel region, large-scale ecosystem-based methods are being employed to revitalize fragile lands and improve livestock productivity. One key practice is rotational grazing, where pastures are divided into sections

BOX 9.9—ROTATIONAL GRAZING FOR ECOSYSTEM RESTORATION IN CHAD

In Chad's Kanem and Bahr el Ghazal regions, long-standing grazing habits had caused serious damage to the rangelands and sparked frequent conflicts among herders. To tackle these challenges, a rotational grazing system has been introduced. Pastures were divided into specific zones, and local agreements were set up to manage when and where herders could graze their animals. This rotation gives the land rest periods to allow vegetation regrowth. Community members monitor the pasture health and adjust the grazing schedules as needed.

This locally managed approach has led to better coordination in land use, easing disputes among herders. As a result, over 15,000 hectares of degraded rangeland showed recovery, and disputes between herders dropped by nearly 40 percent. Beyond environmental benefits, the project also strengthened community cooperation over the sustainable management of their land. The community also developed local rules and institutions to support the system. However, making rotational grazing work requires some upfront investment—in fencing, water access, and thoughtful management that follows plant growth cycles rather than just fixed dates. In consequence, extension services and training are essential to help livestock farmers, both smallholders and larger operations, master these techniques effectively. Nonetheless, this example illustrates how combining traditional knowledge with organized management can restore ecosystems and enhance climate resilience by promoting sustainable pastoral practices in livestock production.

Source: Lininger et al. (2019).

BOX 9.10—CROP BYPRODUCTS FOR LOWER METHANE FROM LIVESTOCK IN BURKINA FASO

In West Africa, many livestock depend on low-quality forage from the rangelands, especially during the dry season. This often leads to weaker animal growth and higher methane emissions from digestion. To tackle this, a recent study examined the effects in Sudanese Fulani zebu steers of replacing a quarter of their usual forage with local crop byproducts, such as straw from maize, sorghum, millet, and rice and legume haulms from cowpeas and peanuts.

The results showed that the legume supplements made a big difference—the steers ate more and their diets had higher protein content. Among the cereals, only rice straw had a noticeable positive effect. Most supplements, except maize straw, helped reduce methane emissions per unit of feed consumed. Specifically, cereal byproducts cut methane emissions by 23 percent, and legume byproducts by 20 percent. These findings offer a practical way for small-scale farmers in the Sahel to improve the nutrition of their animals and cut down on greenhouse gas emissions. By making better use of local crop residues, they can boost productivity while caring for the environment, even with limited resources.

Source: Gbenou et al. (2024).

where animals graze sequentially, allowing plants time to recover before being grazed again (Box 9.9). This mimics the natural feeding behavior of wild herbivores and has been shown to improve soil health, increase soil moisture retention, support biodiversity, and increase carbon sequestration by up to four times more than under constant grazing. It can also cut methane emissions by up to 10 percent, thanks to better forage quality. Additionally, it reduces feeding costs and promotes healthier animals by consistently providing nutrient-rich food. Another approach being examined for reducing greenhouse gas emissions in West African livestock systems is to increase and more effectively use crop residues in livestock diets to cut animal methane emissions (Box 9.10).

- In the tropical agroecologies of Central Africa, there is growing interest in combining crops, livestock, and trees into integrated farming systems. These agroforestry-based approaches support both environmental health and the economic well-being of farming families by improving nutrient cycles, storing more carbon in the soil, and creating multiple sources of income. Trees offer shade, forage, and protect the soil, which together boost animal health and pasture growth. This creates a more circular, sustainable farming system that buffers communities against climate shocks and market fluctuations.

Risk management and financial tools

Livestock plays a crucial role in Africa, supporting people's livelihoods, food security, and overall economic growth. However, the sector faces many challenges, from climate shocks and animal diseases to volatile markets and gaps in institutional support. Strengthening resilience in African livestock systems means adopting strategies tailored to each region, improving financial access for farmers, boosting veterinary services, and fostering effective partnerships between public and private sectors.

- In Kenya, Ethiopia, and Somalia, pastoralism is a major livelihood strategy. However, frequent droughts wreak havoc on grazing lands and water supplies, undermining those livelihoods. To help, innovative solutions like index-based livestock insurance have been introduced (Box 9.11). Insurance payments under the program are triggered if forage availability falls below a specified level. Forage availability is measured through satellite imagery analysis. In addition, government safety-net programs, such as Kenya's Hunger Safety Net Programme, also offer vulnerable pastoral households direct cash support during tough times. Despite these innovations, challenges remain, especially when it comes to managing cross-border livestock trade and controlling diseases, particularly in conflict-affected zones.
- Moving to West Africa, seasonal herd movements are a widespread pastoral practice, particularly in the Sahelian countries. Unfortunately, rising land pressure and insecurity have led to increasing conflict between pastoralists and farmers. Regionally, ECOWAS is stepping in to ease tensions by promoting designated livestock corridors, coordinated vaccination

BOX 9.11—INDEX-BASED LIVESTOCK INSURANCE SUCCESS IN THE HORN OF AFRICA

The Index-Based Livestock Insurance (IBLI) program, launched in 2010 in Kenya and 2012 in Ethiopia, provides insurance coverage for drought-related livestock losses for pastoralist communities in arid and semi-arid regions. By 2024, nearly 50,000 individual policies had been sold across Kenya and Ethiopia, while over 100,000 households benefited through social protection programs. Over five major droughts between 2011/12 and 2018/19, insured pastoralists received timely payouts that helped protect their livestock holdings and livelihoods. In 2014, the Kenyan government scaled up IBLI through the Kenya Livestock Insurance Program. Initially piloted in Wajir and Turkana, the program was expanded to all of Kenya's 14 arid counties by 2016. In Ethiopia, initial scaling up of livestock insurance happened through the Satellite Index Insurance for Pastoralists in Ethiopia Programme. More recently, the De-risking, Inclusion, and Value Enhancement of Pastoral Economies in the Horn of Africa program involves the governments of Kenya, Ethiopia, Somalia, and Djibouti to expand IBLI to reach 1.6 million pastoralists. The program aims to gradually shift recipients toward market-based insurance, supported by partial subsidies.

IBLI relies on satellite-based indices that monitor forage conditions to trigger payouts, avoiding costly individual livestock assessments. This approach reduces fraud and administrative costs while ensuring timely support. Mobile payment platforms, such as M-Pesa, enable efficient premium payments and payouts, while community sales agents and extension services increase local awareness of and trust in the insurance program. IBLI's success as an approach to climate risk management for pastoralists has led to adoption in Tanzania, Sudan, Mauritania, and Zambia.

Source: ARID Kenya (2018); Shikuku and Ochenje (2025).

campaigns, and improved early warning systems for animal diseases. Niger and Mali have also experimented with community-based livestock insurance and feed banks to support herders. Building on Ethiopia's success with the Climate Risk Management for Agricultural Extension (CRMAE) program, Senegal has been working to strengthen climate risk advisory services, training extension workers to better support farmers in managing climate variability (Box 9.12). Early assessments show the training significantly

BOX 9.12—CLIMATE RISK MANAGEMENT FOR AGRICULTURAL EXTENSION (CRMAE) CURRICULUM ROLLOUT IN SENEGAL

A training-of-trainers workshop to launch the Climate Risk Management for Agricultural Extension (CRMAE) program in Senegal significantly strengthened the national Bureau for Professional Agricultural Training (BFPA), boosting their ability to provide climate-smart agricultural extension services to farmers. The training focused on understanding climate risks, improving information delivery, and enhancing communication strategies, paving the way for CRMAE to be integrated into both vocational and education programs. Since 2022, more than 300 extension officers have received this training at Senegal's National School of Agriculture, supported by the initiative.

CRMAE equips extension and advisory service providers with tools to interpret seasonal forecasts and climate data and provides them with training on climate-risk management approaches, helping them better support farmers and agro-pastoralists. Importantly, the training curriculum under CRMAE was adapted through local consultations to make sure it fits Senegal's specific needs.

With CRMAE now part of the country's national agricultural training system, extension officers are empowered to offer tailored climate advice that helps farmers respond to challenges like droughts, floods, and other climate-related threats. This initiative is playing a vital role in advancing Senegal's goals for climate resilience, food security, and sustainable rural development.

Source: Hansen et al. (2024).

improved participants' knowledge and ability to apply climate shock management and mitigation tools in the field, with high relevance reported across all curriculum modules.

- In Southern Africa, livestock systems are more mixed. Botswana, Namibia, and South Africa have strong commercial sectors, with Botswana's beef industry relying on rigorous animal traceability and disease-free zones to maintain market access to the European Union. On the other hand, the smallholder farmers who dominate livestock production in Zambia and Zimbabwe often struggle with limited veterinary services and challenges reaching markets. However, they benefit from public vaccination drives and new livestock financing options.
- In Central Africa, deep challenges like insecurity and weak infrastructure hinder the provision of formal risk management systems in national livestock systems. Livestock keepers in the region mainly depend on traditional coping strategies and informal cross-border trading. At the same time, there is increased interest in improving regional coordination on animal health, with institutions like the Commission Économique du Bétail, de la Viande, et des Ressources Animales (CEBEVIRHA—Economic Commission for Livestock, Meat, and Animal Resources) under the Economic Community of Central African States (ECCAS) playing a leading role.
- Lastly, in North Africa, Morocco, Algeria, and Egypt face ongoing risks to livestock production from water scarcity and feed shortages. National and local governments support livestock farmers through measures such as feed subsidies, building strategic feed reserves, and implementing national livestock development plans, often with a focus on strengthening dairy and meat value chains.

Animal health innovations

Animal health is a cornerstone of livestock productivity and resilience across Africa. The continent struggles with widespread diseases like contagious bovine pleuropneumonia, foot-and-mouth disease, Rift Valley fever, and peste des petits ruminants (PPR). Vaccination and other animal health innovations play a vital role in managing these threats, though their implementation varies widely between regions.

- In the Horn of Africa, where mobile pastoralist communities and limited infrastructure make traditional veterinary services hard to reach, Kenya and Ethiopia have introduced Community Animal Health Workers to bring vaccinations and basic veterinary care directly to remote areas. Ethiopia has also tested drones to deliver livestock vaccines to hard-to-reach pastoralist settlements. Regional bodies like the IGAD Centre for Pastoral Areas and Livestock Development coordinate disease monitoring and synchronize vaccination efforts to tackle cross-border challenges (ICPALD and FAO 2023).
- In West Africa, especially in Niger, Mali, and Burkina Faso, frequent disease outbreaks are worsened by seasonal livestock movements and open borders. Continent-wide and regional organizations, such as AU-IBAR and ECOWAS, have launched large-scale vaccination campaigns and support mobile clinics that travel with herds. Several countries have built animal vaccination into their broader drought preparedness plans. To combat PPR, both Mali and Nigeria have introduced thermotolerant vaccines, which do not require cold storage, making them ideal for administration in remote areas (Box 9.13).
- Southern Africa's animal health systems tend to be more developed. Botswana and Namibia maintain strong public veterinary services and enforce annual vaccinations against ailments like foot-and-mouth disease and anthrax, helping secure their positions in lucrative beef export markets. South Africa has adopted digital tracking systems for animal health and fostered public-private partnerships to boost vaccine production.
- In Central Africa, ongoing conflict and governance challenges often disrupt the consistent implementation of livestock vaccination programs. Chad and the Central African Republic often rely on donor-supported initiatives. Regional groups, such as CEBEVIRHA, are working to improve collaboration on animal health surveillance and harmonize veterinary protocols across borders.
- North African countries, such as Morocco and Egypt, run well-established state-led livestock vaccination programs, often tied to broader national food security efforts. New approaches include mass vaccination campaigns, e-health tracking technologies, and partnerships with private veterinary providers.

BOX 9.13—THERMOTOLERANT PESTE DES PETITES RUMINANTS (PPR) VACCINES IN MALI

Peste des petites ruminants (PPR) poses a serious threat to Mali's rural economy, where over 80 percent of the population depends on livestock. Despite the country's national vaccine production capacity, only 9 percent of small ruminants were vaccinated in 2023, primarily due to logistical constraints and the reliance on a thermolabile vaccine that requires constant refrigeration. OvipestePlus, a thermotolerant PPR vaccine developed by ILRI, LCV Mali, and Hester Biosciences, retains potency for nine days at 38.5°C and for five hours post-reconstitution, outperforming the current vaccine. It is 99 percent effective and validated for broader regional use.

A cost-effectiveness analysis showed that thermotolerant vaccines reduce vaccine wastage and offer lower costs per averted loss, especially in remote regions, compared to traditional cold chain-dependent vaccines. Mali seeks to attain 80 percent PPR vaccination coverage by 2030, with vaccine production increasing from 15 million to 26 million doses annually, predominantly using thermotolerant strains. The cost-effectiveness analysis estimated that the program provides a benefit-cost ratio of 33.8. Mali is poised to become a regional hub for the supply of thermotolerant PPR vaccine to its West African neighbors as part of a continental effort to eradicate PPR.

Source: Dione et al. (2025).

Community-based resource governance and learning

Managing resources effectively and fostering strong learning systems are necessary if new technologies in Africa's livestock sector are to be adopted fairly and sustainably. Many African countries are turning to community-based approaches for managing their livestock resources and sharing knowledge, especially in rangeland and pastoral areas. Since grazing lands and water sources are commonly shared, local institutions and traditional practices often serve as the first line of defense against land degradation, conflicts over resources, and climate-related challenges.

- In Ethiopia, Kenya, and Somalia, traditional bodies like dedas (elders' councils) and pastoralist associations oversee how pasture and water are used. These groups help manage seasonal herd movements and resolve disputes between herd owners. For example, in northern Kenya, grazing committees work together with community conservancies to blend indigenous wisdom with innovative tools, such as participatory rangeland management, to monitor land health and regulate land use.
- In West Africa, countries like Mali, Niger, and Burkina Faso have a rich history of community governance through land charters, herder cooperatives, and transhumance committees. These groups coordinate access to grazing corridors and water during dry spells. In Mali, supported by organizations like ECOWAS and various non-governmental organizations,

legally recognized local agreements, called conventions, help balance land use among farmers, herders, and fishers (Box 9.14). In Niger, community learning groups also play a vital role by sharing climate adaptation strategies, like fodder production and water harvesting.

- In Southern Africa, communal grazing systems, such as those in Zimbabwe and Namibia, involve traditional rangeland management practices like rotational grazing and bush clearing, typically overseen by traditional leaders and village committees. Non-governmental organizations encourage knowledge sharing through community learning platforms and farmer field schools to boost livestock management skills. In Botswana, community trusts run grazing areas within wildlife management zones, balancing both livestock needs and wildlife conservation efforts.

TABLE 9.1—EMPOWERING WOMEN AND YOUTH THROUGH LIVESTOCK INNOVATION

Technology Area	Opportunities for Women	Opportunities for Youth	Risks of Exclusion	Recommendations
Genetic Improvement	Better breeds can boost milk yields Enable women to provide better nutrition to families and earn	Youth can get skilled jobs related to breeding, e.g., artificial insemination technicians	Women and youth may lack capital or control of land	Offer gender-sensitive training Support youth-led breeding Ensure women's livestock ownership
Feed Innovation	Women can earn from alternative feed pathways, e.g., black soldier flies or farming forage crops	Good for youth entrepreneurship via creation of jobs along livestock feed value chains	Limited funds and training block access	Provide microcredit and support cooperatives
Digital and Mobile Technologies	Women obtain tailored veterinary and market information	Youth are attracted to and may gain skills in agricultural technologies	Phone and internet gaps limit access	Combine mobile with radio Subsidize phones for women and youth
Climate-smart Technologies	Women benefit from improved feeding methods	Youth can lead rotational grazing initiatives	Women's roles overlooked Youth may leave	Include women and youth in climate groups Reward leadership
Risk Management and Finance	Insurance helps women-headed households	Youth attracted to micro-insurance and credit	Lack of trust and literacy barriers	Design gender and youth-friendly insurance and financial products Train insurance agents from these groups
Vaccination and Animal Health	Easier vaccine access stabilizes women's income	Paid jobs as vaccinators and record-keepers	Women and youth excluded from training and data tools	Set quotas for participation of women and youth Align training with quality products Bundle with business skills and insurance
Community Governance and Learning	Women get a stronger voice in resource committees	Youth engagement offers alternatives to risky migration	Power grabs can exclude women and youth	Require leadership quotas Fund youth and women-led monitoring

Source: Compiled by authors.

- Central Africa, though less organized, is seeing promising developments in countries like Chad and Cameroon. Here, participatory mapping and inclusive planning help communities take better control of shared grazing lands. Technologies like community radio and mobile learning units are increasingly used to spread important information in remote pastoral areas.
- In North Africa, Morocco supports collective action through pastoral cooperatives and local councils that oversee grazing areas and lead reforestation projects. Training programs help merge climate-smart solutions with traditional local knowledge.

Linking Gender, Youth, and Livestock Technology for Growth

Inclusive, participatory approaches that factor in gender and youth are crucial for the successful, widespread, and effective uptake of new technologies to empower livestock farming communities and boost productivity in the sector. Livestock innovations have great potential to improve rural livelihoods by creating meaningful opportunities for women and youth (Table 9.1). Women can benefit from improved livestock breeds, climate-smart feeding methods, digital advisory services, and inclusive financial tools, which increase productivity, reduce labor burdens, and stabilize household incomes. Youth can employ these technologies to access new career paths in animal health services and micro-entrepreneurship ventures, like insect-based feed production and digital finance solutions. These developments position women and young people as important contributors to advancing climate-smart agriculture, improving food security, and building greater resilience in household livelihoods.

However, structural barriers limit their full participation. Women often have restricted rights to land and livestock ownership, face gaps in their access to digital tools, have lower financial literacy, and are often excluded from community decision-making processes. Youth face challenges in expanding their enterprises to establish sustainable livelihoods and, like women, are often excluded from decision-making. Without deliberate efforts targeted at women and youth, innovations in livestock farming across Africa may unintentionally reinforce existing social inequalities.

To fully capitalize on these opportunities, policies must incorporate gender- and youth-sensitive strategies, such as promoting shared ownership

models, establishing representative quotas in governance and certification bodies, expanding tailored financial services, and investing in inclusive digital infrastructure. These measures will not only guarantee fair access and benefits but also enhance systemic resilience within the livestock sector in Africa, supporting a more sustainable and inclusive future.

Cross-cutting Themes

Across Africa, the intersection of digital innovation —such as IoT, mobile technology, and big data—with climate-smart practices, supported by inclusive community involvement and favorable policies, is sparking transformation in livestock services. This shift is helping build more innovative, sustainable, and resilient animal farming systems worldwide (El Idrissi et al. 2021). Several common themes emerge as livestock services evolve:

Digital transformation is rapidly reshaping how livestock support is delivered. Mobile phones and IoT devices are making it easier for farmers to access veterinary care and to obtain market updates and weather advisories in real time. For instance, sensors and other wearable technologies can monitor animal heart rates, temperatures, and behavior, spotting illness early and improving overall welfare. GPS-enabled smart collars help track herds and boost their safety, while cloud-based platforms and apps allow farmers to manage their livestock remotely and more efficiently. These technologies work particularly well under appropriate incentives and where there are low barriers to adoption, i.e., in contexts where a significant share of livestock farmers own smartphones and there is good access to the internet. In settings where barriers to adoption exist, combining other forms of communication with mobile technologies can be helpful. Examples of such forms of communication include broadcasting audio messages through community radio stations or utilizing advertising spots on television.

Climate-smart technologies are now central to the implementation of national strategies for adaptation to climate change and mitigation of climate change-related shocks. The development of innovations like methane-reducing feeds, drought-resistant forages, and thermostable vaccines has been prioritized to sustain the growth of livestock sectors. These tools lower the environmental footprint of the livestock sector, help animals withstand the challenges brought on by changing climates, and align livestock production practices with broader sustainability goals.

Supportive policies and institutional frameworks are essential to integrate and expand the use of digital and climate-smart tools. Readiness to adapt to new digital methods, policies that encourage e-agriculture, and investments aimed at modernizing veterinary services all help create a foundation for sustainable livestock management.

Challenges and Opportunities

The level of adoption of livestock innovations across Africa varies significantly. Countries like Kenya and South Africa are leading the way, supported by robust infrastructure, enabling policies, and active private sector participation. In contrast, many nations in the Central Africa region face challenges due to weak institutions, limited market access, and inadequate infrastructure.

Women, who constitute 60 to 80 percent of small ruminant producers, play a crucial role in the livestock sector but encounter persistent barriers, including restricted land ownership, limited access to credit, and difficulties adopting new technologies. Digital finance platforms, such as M-Pesa, have opened new avenues for savings and credit, yet gaps in digital literacy and access to devices continue to limit their full potential. Young people are increasingly engaging in the use of agricultural technologies, animal health, and insect-based feed ventures, which create employment and broaden livelihood opportunities. However, their progress is hampered by limited startup financing and insufficient business training.

Equity remains a significant hurdle. For example, early livestock subsidy programs in Kenya primarily benefited wealthier farmers, and subsequent reforms have only partially addressed these disparities. Broader adoption of innovations is still constrained by insecure land tenure, fragmented service delivery, inadequate infrastructure, and the high initial costs associated with new technologies that hold promise for livestock farmers. For livestock innovations to foster inclusive growth, policies must intentionally address the needs of women and youth. Key priorities include promoting joint ownership of land and livestock assets, enhancing representation of these groups in governance structures, expanding customized financial services, and investing in digital infrastructure.

Successful examples of adoption of innovative technologies in the livestock sector, such as Kenya's Index-Based Livestock Insurance and Mali's thermostable vaccine programs, demonstrate how strong institutions and focused interventions

can accelerate technology uptake. Livestock innovations offer powerful opportunities to boost productivity, resilience, and food security. Realizing these benefits hinges on inclusive strategies that ensure equitable access and actively prevent the deepening of existing inequalities.

Scaling Pathways and Policy Recommendations

For technologies to reach their full potential across livestock systems, governments need to integrate climate-smart livestock technologies into national strategies. Doing so will ensure alignment with larger policy goals, consistency in implementation, and sustained impact. Investing strategically in critical infrastructure, such as rural connectivity, veterinary infrastructure, and digital services, is vital to expanding access to emerging livestock technologies, especially for farmers in underserved areas.

Public-private partnerships are critical to accelerating the adoption of innovation. By combining the strengths of research institutes, information and communication technology companies, businesses in the agrifood sector, and financial services with those of government agencies, these collaborations will enable the effective scaling of livestock technologies and their adaptation to local contexts. Critical for achieving this will be the establishment of a favorable business environment in the livestock sector by political leaders to stimulate the interest and resources of all stakeholders.

It is crucial to facilitate inclusive finance for women and youth livestock keepers. Targeted financial tools, such as smart subsidies, concessional loans, performance-based incentives, and access to climate finance, are crucial to reduce risks for smallholder livestock farmers adopting new methods. These mechanisms make technologies for the sector more affordable and lower the barriers to shift toward climate-smart and more productive livestock production practices.

Finally, it is critical to promote regional frameworks for standardized animal health and trade regulations. The regional bodies, ECOWAS and IGAD, are already playing strong roles in promoting cross-border collaboration on livestock production and marketing. Through harmonizing veterinary and trade standards, aligning policies, and encouraging knowledge sharing, these regional organizations help improve market access and strengthen livestock value chains against shocks.

Conclusion

Emerging technologies are reshaping what is possible for Africa's livestock systems, opening up powerful new pathways to overcome longstanding challenges, boost resilience, and create economic opportunities for millions of livestock producers. The real question now is not whether to adopt these innovations. Rather, it is how to scale them out widely and fairly. Crucially, scaling efforts should consider heterogeneity in contexts in terms of sociocultural, political, and economic realities.

Building resilient and competitive livestock sectors involves more than just technology. It also requires effective management and strategic planning, political commitment, institutional reform, and genuine inclusion. When innovation is paired with strategic investment and supportive policies, livestock can stop being a source of vulnerability and become a foundation for sustainable development.

It is also important to bear in mind that, with the growing frequency of shocks—whether from climate events, pandemics, market or other economic dislocations, as well as social and political instability—no single solution is enough. The complexity of these challenges demands integrated approaches that combine multiple tools, technologies, and practices to strengthen overall system resilience and maximize beneficial impacts on the livelihoods of livestock farmers and the broader economies of interconnected sectors.