CGIAR MULTIFUNCTIONAL LANDSCAPES

Agroecology in livestock systems in low- and middle-income countries: Managing synergies and trade-offs

2025

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Citation
Masso, C., Alary, V., Burkart, S., Caron, A., Ezekannagha, O., Flintan, F., Frija, A., Geck, M. S., Habermann, B., Kumar, G., Kumar, S., Malaiappan, S., Notenbaert, A., Rasche, F., Upla, P., Vall, E. and Wane, A, Whitbread, A. (2025). Agroecology in livestock systems in low- and middle-income countries: Managing synergies and trade-offs. CGIAR Multifunctional Landscape Program.

Acknowledgments
This work was implemented and funded by the CGIAR Multifunctional Landscape Program. We would like to thank all funders who supported this research through their contributions to the CGIAR Trust Fund.

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1. Executive summary

Livestock systems are central to rural economies, food security, and cultural identity across low- and middle-income countries (LMICs), particularly in the tropics. They also strongly influence diet quality and food safety. Yet these systems are increasingly strained by environmental degradation, including tropical deforestation linked to cattle production, large-scale monocropping of feed crops, persistent malnutrition, and intensifying climate change. Current global recommendations to reduce meat consumption often overlook regional nutritional needs and the socioeconomic realities of LMICs, contributing to widening inequalities. These challenges highlight an urgent need for policies that support transformative, locally-approproate change.

Agroecology offers a practical and evidence-based pathway to making livestock systems more sustainable, climate-resilient, and equitable. By integrating ecological principles with traditional knowledge, diversified production, and social inclusion, agroecological livestock systems can reduce environmental impacts, improve animal health and productivity, support safer and more diverse diets, and strengthen livelihoods through circular nutrient flows and resource efficiency.

This white paper synthesizes current research, guiding principles, practical approaches, and policy considerations for advancing agroecological practices in LMICs' livestock systems. It examines the interconnections among animal health and productivity, environmental management and health, and human health including nutrition and well-being, drawing on insights from global communities of practice working on multifunctional landscapes. It advocates for policies that balance productivity with environmental stewardship and social justice, emphasizing the need for adaptive strategies that reflect local ecological, economic, and cultural context rather than "one-size-fits-all" solutions.

Selected case studies from Africa, Asia, and Latin America illustrate feasible, context-specific entry points for scaling agroecological livestock systems. Together, these insights equip policymakers with actionable pathways to foster resilient food systems capable of meeting nutritional needs, sustaining rural livelihoods, and contributing to climate and environmental goals.

2. Background and context

Livestock play a far-reaching role in LMICs, beginning with nutrition and extending to livelihoods, culture, and ecosystem management. Animal-source foods—often consumed in small but frequent amounts—provide highly bioavailable iron, zinc, calcium, vitamin B12, and high-quality protein (Adesogan et al. 2020), making them essential for diet quality and the nutritional needs of vulnerable populations. Globally, 40% of the value of agricultural inputs stems from the livestock sector and around 1.3 billion people depend on it for their livelihoods and food security (Food and Agriculture Organization of the United Nations [FAO] 2016). Terrestrial animal source foods provide on average 21% of global caloric supply, the highest share being in North America at 48% and the lowest in Western Africa at 4% (FAO 2023).

Beyond food, livestock are a cornerstone of pastoral and mixed farming systems in LMICs. They function as capital assets, buffer against shocks, sources of traction, fertilizer, and energy, and are foundations for social and cultural life (Alonso et al. 2019). The integration of livestock with crops and other farm enterprises supports nutrient cycling, energy flows, landscape management, and risk diversification (Alary et al. 2020; Sekaran et al. 2021). Interestingly, rangelands provide several important ecosystem services (United Nations Convention to Combat Desertification [UNCCD] 2024). They sustain 500 million pastoralists while supporting biodiversity, carbon storage, and water regulation. They provide food, fiber, and income, reduce poverty, strengthen climate resilience, and protect cultural heritage.

Given the vast land area involved—about 80 million km² globally and roughly two-thirds of the African continent (Bolo et al. 2019)—sustainable livestock management is central to meeting biodiversity, climate, and land restoration commitments under the Rio Conventions. This urgency is heightened by concerns over deforestation linked to cattle and feed production, greenhouse gas (GHG) emissions, unsustainable land and water use, and pollution. Drylands, which host 78% of global rangelands (Rangelands Atlas, n.d.), are particularly vulnerable and require careful stewardship. Although global livestock systems contribute significant emissions, evidence from smallholder contexts shows that agroecological and well-managed systems can approach carbon neutrality through improved soil and vegetation carbon sequestration.

Box 1: Mixed crop–livestock farming in India

In the Global South, livestock has traditionally been integral to farming systems. In India, mixed crop–livestock farming evolved as a self-sustaining model where animals provide manure for soil fertility, draught power for land preparation, and nutrition through milk and by-products. Community-managed natural farming initiatives, like in Andhra Pradesh and Gujarat, have revived these practices using farm-derived inputs like cow dung and urine-based formulations, integrated fodder crops, and strengthening local circular economies. In many tribal regions, livestock are kept primarily for manure and land preparation, underscoring the link between animal husbandry, soil health, and farm productivity.

According to the World Resources Institute, land conversion to cattle pastures, between 2001-2015, resulted in deforestation of 45 million hectares globally, and mainly in Latin America e.g., Brazil, Paraguay and Colombia (Goldman and Weisse 2024). Livestock systems are also associated with GHG emissions, the majority of which originate from feed production, ruminant enteric fermentation, and storing of manure (FAO 2023). However, in smallholder farming systems, agroecological or well-managed livestock systems could be carbon neutral as a result of carbon sequestration by soils and plants, as reported in Northern Senegal (Assouma et al. 2019). Importantly, the environment-animal/livestock-human nexus requires sustainable management to minimize One Health issues and the occurrence of zoonotic diseases (Caron et al. 2016; Gilbert et al. 2021).

The sector is also shaped by complex social and governance dynamics, including gender inequality, land tenure disputes, and limited access to land and other resources for marginalized communities (Galiè et al. 2019). Such inequities are pronounced in regions like the Horn of Africa, where overlapping institutional systems, mobility constraints, and historical marginalization compound local tensions (World Bank Group 2020). Similar patterns of inequality are evident across pastoral and agropastoral systems, with high Gini indices reported in Mongolia, Argentina, and the Sahel (0.47–0.71 between 2017 and 2020) (Wane et al. 2020; Wane et al. 2024). These disparities are largely driven by unequal access to rangelands, infrastructure, and essential services. Against this backdrop, agroecological principles are increasingly embraced for their emphasis on resource efficiency, social inclusion, cultural cohesion, resilience, and participatory governance (Matiello et al. 2018; Volpato et al. 2019).

Agroecology offers a unifying framework to address these interconnected environmental, economic, social, and governance issues. Rather than a single technology, agroecology applies ecological science to agriculture through practices rooted in traditional knowledge, co-creation of innovations, and participatory governance. It aims to enhance resilience, improve synergies among plants, animals, people, and ecosystems, regenerate biodiversity, and support fair and inclusive food systems.

This white paper delves into the importance of livestock for sustainable development, articulates the principles of agroecological management, analyzes barriers and enablers for transformation, presents policy options, and recommends concrete actions. Utilizing global research, insights from communities of practice dedicated to multifunctional landscapes, alongside contemporary case studies, it offers a practical framework for policymakers, development practitioners, researchers, and communities. It examines the synergies and trade-offs across agroecological principles to help guide policies that balance productivity, sustainability, economic opportunity, and social inclusion in livestock systems.

3. Agroecological principles in livestock systems

Agroecology in livestock systems is defined not by a single practice, but by the integrated application of ecological, economic, and social principles, aligned with Committee of World Food Systems' (CFS) recommendations linking production to healthy diets, food safety, antimicrobial resistance stewardship, and gender equity. Below is an overview of the thirteen agroecological principles applied to livestock systems.

3.1. Recycling

Well-managed livestock systems can convert agricultural by-products (e.g., crop residues, food waste) into high-value outputs—meat, milk, manure, fiber, and energy. Integrated nutrient recycling enriches soil organic matter, improves soil structure and water retention, and reduces dependency on synthetic fertilizers. For example in Kenya, mixed crop-livestock farms use manure from dairy cattle to fertilize maize fields, boosting yields while closing nutrient cycles and reducing costs (Snijders et al. 2013). Similar benefits were demonstrated by the CGIAR research initiative on agroecology (2022-2024) in countries like Burkina Faso, India, Kenya, Senegal, and Tunisia (Vall et al. 2023; Alary et al. 2025).

However, recycling rates for farm and livestock co-products are often low in LMICs, estimated at <40% in West African countries like Burkina Faso (Zoungrana et al. 2023), and there remains significant room for improvement to increase the efficiency of recycling the crop and livestock biomasses. Thorough understanding of nutrient composition in manure, availability, and optimal application rates for specific crops and contexts would lead to achieving sustainable impacts. Manure is a strategic resource for circular bioeconomy, delivering not only plant nutrients and soil carbon, but also renewable energy through biogas model for clean cooking reducing reliance on firewood improving air quality, mitigating deforestation, while enhancing soil fertility. Other circular economy principles include crop residues application for mulching, incorporation for soil fertility, and use of crop residues to feed livestock among several options (Duncan et al. 2023).

3.2. Input reduction

This agroecological principle can be applied to at least four system components: feed, fertilizer, weed/pest control, and water. Prioritizing low-input practices across these dimensions lowers production costs, mitigates environmental impacts, and supports animal health. The transition towards input-efficient systems not only contributes to climate change mitigation but also strengthens local input self-sufficiency and enhances the adaptive capacity of smallholder farming and herder communities.

Feed

Cultivated forages can reduce the need for commercial feed and supplements by improving feed efficiency and quality. When well-managed, and harvested or grazed at the optimal growth stage, they offer higher metabolizable energy and protein per unit area, allowing moderately productive animals to be raised with little or no concentrate use.

Crop residues provide the major feed source for livestock in these systems. While the overall nutritive value of crop residues is typically limited, fodder traits vary widely across crop cultivars. This diversity offers opportunities to improve livestock productivity. For example, sheep fed with faba bean straws or groundnut haulms from specific cultivars show live weight gains up to twice as high as those fed other varieties (Prasad et al. 2010). In major cereal crops such as sorghum, maize, rice, wheat, and barley, feed quality can also be improved by selecting for superior fodder traits without compromising grain yield. Integrating these traits into existing and new crop varieties can strengthen the value of food-feed crops while remaining compatible with other agroecological practices, including conservation agriculture (Valbuena et al. 2012). Dairy farming systems are driven by the market (mini-dairy processors) and low-cost intensification, which involves a livestock farming system that includes daily grazing of rangelands, storage and distribution of crop co-products (haulm, straw) and small amounts of purchased feeds such as cottonseed meal and cereal bran (Vall et al. 2021).

Box 2: Turning waste into feed, fertilizer, and livelihoods in Kenya

Farmers in Western Kenya are transforming local agriculture through community-led Black Soldier Fly (BSF) farming, converting organic waste into valuable fertilizer and protein-rich livestock feed as an affordable, sustainable alternative to conventional animal feed. The initiative improves soil health, increases farm productivity, and creates additional livelihoods to the farming community. Beyond production, the BSF farming plant has served as a training hub, equipping over 46 farmers at the aggregated farms with the skills to replicate this model on their farms, further amplifying its environmental and economic benefits. The sector will benefit from quality assurance and control mechanisms.

Fertilizer

Forage legumes reduce fertilizer requirements through symbiotic nitrogen fixation, while forages can be used as green manure. Increased livestock productivity also leads to more on-farm manure availability, complemented by crop residues freed up for soil amendments once forages replace them in feed rations. In Argentina, rotational grazing systems on native grasslands support healthy soils and biodiversity, with minimal external inputs (Baronti et al. 2022; Muchiutti et al. 2024). Similar findings were reported by Alary et al. (2020) in Egypt, where, rotation of cereal-leguminous crops, particularly those including berseem (*Trifolium alexandrinum*), in the Nile delta resulted in improved soil fertility, while providing valuable forage for cattle and buffaloes.

Tropical pastures, most notably Brachiaria pastures, have also been identified as a source biological nitrification inhibition, where root exudates suppress soil-nitrification thereby reducing nitrogen losses from the system (Subbarao et al. 2009; Byrnes et al. 2017; Nuñez et al. 2018).

Weed and pest control

Forages, used as cover or companion crops, reduce the need for weeding and herbicides. Pest- and disease-tolerant forage varieties, or forages integrated into push–pull systems, substitute for chemical pest control against challenges such as stemborers and *Striga*.

Water

Cultivated forages improve soil water retention and infiltration when used as cover crops or green manure, rehabilitate degraded pastures, and reduce run-off. Drought-tolerant and water-saving forages further decrease dependence on irrigation compared to traditional forage species. In many African systems, improved water harvesting, distribution, and use efficiency are essential to reducing irrigation demand while ensuring stable forage yields and resilient livestock production.

3.3. Soil health

Soils are among the planet's largest reservoirs of biodiversity, hosting an estimated 59% of all species (Anthony et al. 2023). Recognizing this importance, initiatives such as CGIAR's "Multifunctional Landscapes" and "Sustainable Farming" programs, together with the African Union's Soil Initiative for Africa (SIA), prioritize restoring soil organic matter, strengthening nutrient cycling, and improving nutrient use efficiency. Within livestock systems, cultivating forages is a promising pathway for rebuilding soil health and function.

Rotational grazing and planned rest periods help sustain soil fertility and support diverse microbial communities (Ma et al. 2022; Moore et al. 2023), which underpin productive, climate-smart livestock systems. Tools integrating traditional knowledge with modern technologies, such as the Land-Potential Knowledge System (LandPKS) app, have improved grazing decisions management and soil health in countries like Tunisia. In West Africa's savannah zones, research has strengthened manure management (Blanchard et al. 2013) and co-designed crop-livestock integration practices to enhance soil fertility (Dongmo et al. 2012), with recent extensions to dairy systems in Burkina Faso (Ouattara et al. 2024).

Manure application, recycling forage residues, and livestock droppings enhance soil microbial diversity and activity, accelerating the formation of stable soil carbon (Rasche and Cadisch 2013). Microbial life underpins nutrient and carbon cycling in agroecosystems, regulate key biogeochemical processes, and improve soil structure and nutrient-use efficiency under low-disturbance management (Wu et al. 2024).

3.4. Animal health and welfare

Attention to animal welfare—through pasture access, diverse diets, low-stress handling, and limited antibiotic use—supports robust animal health, reduces disease risks, and safeguards public health. Pasture-based dairy systems reduce infectious and metabolic diseases by providing fresh air, exercise, and natural diets, and are associated with lower rates of lameness and mastitis (Washburn et al. 2002). Maintaining animal health is essential both for safe, nutritious animal-derived foods, and for preventing zoonotic diseases.

High-quality forages, including legumes, improve feed quantity and quality, enhancing immunity and disease resistance. Conserved forages (hay, silage, pellets) provide feed during periods of scarcity, reducing animal vulnerability to disease. Diverse pastures supply complementary nutrients and beneficial secondary compounds, while tannin-rich plants show promise for managing gastrointestinal parasites without commercial drugs. Silvopastoral systems enhance welfare by providing shade and moderating heat stress. These forage-based practices reduce antibiotic use, lower antimicrobial resistance risks, and diminish pathogen loads in manure. They also reduce reliance on contamination-prone feeds such as aflatoxin-affected maize, improving animal and human health (Notenbaert et al. 2021).

In pastoral systems where livestock co-exist with wildlife, disease transmission risks—as seen between livestock and African buffalo—require integrated management of the wildlife-livestock-pastoralist interface (Caron et al. 2013; de Garine-Wichatitsky et al. 2021). Combining traditional and modern approaches to reduce disease, competition for food and even predation in the case of carnivores. Animal and wildlife health are central to sustainable pastoral management.

Ethnoveterinary practices, such as the long-standing use of medicinal plants in Afghanistan (Davis et al. 1995), and precision feeding with bioactive forages support resilience and productivity. Good animal welfare directly contributes to productivity; for example, in Western Africa, keeping dairy calves with their mothers reduces stress, stimulates milk secretion, and extends the milk production period (Vall et al. 2021).

3.5. Biodiversity

Biodiversity underpins pastoral societies by sustaining livestock production, livelihoods, and cultures. Soil biodiversity is the nutritional basis of pastures and their trees, supporting primary production that feeds livestock and co-existing wildlife. Pastoral societies have traditionally maintained the ecosystem functionality and biodiversity because their own sustainability depended on it.

Diverse, mixed farming systems integrate crops, livestock, soils, and trees, leveraging ecological interactions for pest control, pollination, and nutrient cycling. These systems increase productivity, buffer against shocks, and sustain ecosystem services. In silvopastoral systems, shrubs and trees positively affect biodiversity by creating complex habitats for wild animals and plants and harboring a richer soil biota as compared to conventional grazing systems. Broader variety of plant species in combination with reduced use of chemical weed/pest control products is likely to attract and maintain wider diversity of e.g., pollinators and below-ground fauna.

Integrating livestock, enset, and coffee or other crops enhances food security by diversifying household diets and reducing risk from crop failure. It increases income through multiple revenue streams and promotes landscape diversity, which supports ecosystem resilience. For example, in southern Ethiopia, smallholders who combine enset, coffee, and livestock achieve more self-reliance (Blomme et al. 2023). In the Sudano-Sahelian region in countries like Senegal, agroecological transition models integrate agriculture, forestry, and pastoral activities through community-led pathways that restore land, increase crop yields, and strengthen community engagement.

Biodiversity is also favored by animal species diversity, using (and then stimulating) different plant species. This biodiversity increased with animal mobility that dispatched plant seeds between different habitats (Selemani 2020). In the near future, well-preserved biodiversity maintained by pastoral societies could contribute more effectively to addressing the biodiversity crisis through the recognition of pastoral areas as Other Effective Area-based Conservation Measures (OECMs) (Jonas et al. 2024).

3.6. Synergy

Synergy arises from integrating multiple components—crops, livestock, biodiversity, and local knowledge—so they interact positively, amplifying overall agronomic and ecological system performance and resilience. In LMICs, this is often achieved by blending animal husbandry with crop and forestry practices, such as in silvopastoral systems where trees provide shade and fodder, livestock contribute manure for soil fertility, and diverse pastures support both animal health and ecosystem services. These interactions increase resource use efficiency and reduce reliance on external chemical inputs, as natural processes like nutrient cycling, pest control, and pollination are enhanced. Cultivated forages capture nutrients from across the soil profile and make these available to livestock, while livestock can convert marginal lands into productive areas that may otherwise be unsuitable for alternative forms of agriculture.

Participatory rangeland management further exemplifies synergy by involving local communities in decisions about grazing, integrating productive areas and shrubs for browsers, which boosts livestock productivity, soil health, and biodiversity. When knowledge co-creation brings together farmers, extension workers, and researchers, innovative solutions emerge that are tailored to local challenges, ensuring sustainable increases in productivity and resilience to shocks. Collectively, these agroecological synergies promote food security, economic potential, and environmental stewardship, especially critical for smallholders in resource-limited contexts. Synergy between pastoral systems and wildlife tourism-economy can in some contexts leverage win-win solutions both for pastoral societies and biodiversity.

3.7. Economic diversification

Livestock contribute to multiple income streams—meat, milk, eggs, fiber, manure, draught power—that reduce financial risk and enhance rural prosperity. In Malawi, dairy farmers have more food self-sufficiency as a result of better yields and diverse sources of income (Banda et al. 2021). In Burkina Faso dairy farms that are most advanced in the agroecological transition achieve the highest performance scores in terms of income diversification and stability (Orounladji et al. 2025). Beyond crops, aggregated farms in Western Kenya facilitate ventures into forage and fodder production, black soldier fly farming, poultry, aquaculture, and compost/organic manure production. By diversifying their production and combining resources, farmers can maximize yields, reduce risks, and access new value chains, making them more competitive and sustainable within the agricultural economy. Capacity sharing in Murehwa (Zimbabwe) in poultry farming (i.e., Sasso Poultry Production), including connecting producers (farmers), buyers, and experts, resulted in income and diet diversifications, improving access to meat, eggs, and chicken manure for better crop yields. Women participation in the Sasso Poultry Production was over 70%, enhancing the financial autonomy.

In the drylands, grazing livestock systems are also based on a multi-species herd (e.g., sheep and goat with camels or bovine), enhancing animal products and co-products diversity (meat, milk, manure, wool, hides and skins, transport etc.) in the food systems and income portfolio. This diversity ensures the function of providing for urgent cash expenses and food self-sufficiency in the short term and the overall family investment plan in the medium or long term (Alary et al. 2022).

In India, integrated farming systems advocated by natural farming programs illustrate how smallholders can incorporate livestock, horticulture, and field crops in both spatially and temporally diverse arrangements. These approaches enhance resource-use efficiency, provide income from various streams, and strengthen resilience against market or climatic disruptions.

In some pastoral systems, such as in Eastern and Southern Africa, the conservation of large African wildlife has recently enabled pastoral societies to diversify their income by linking them to the wildlife tourism sector.

3.8. Co-creation of knowledge

Co-creation of knowledge in livestock systems brings together diverse stakeholders, including pastoralists, indigenous communities, extension services, researchers, and policymakers among others, enabling solutions that balance ecosystem health, livestock productivity, economic potential, and social inclusion. Collaborative approaches integrate scientific, local, and traditional expertise, fostering innovations that are ecologically sustainable, economically viable, and socially equitable (Pretty et al. 2009; FAO 2018). A step-by-step approach to co-designing knowledge and innovations has been successfully implemented in several local dairy value chains of sub-Saharan African countries, working with multi-stakeholder platforms (Vall et al. 2025).

Participatory Geographic Information Systems (PGIS) play a central role in co-creating knowledge that bridges scientific data and local experience. Through PGIS mapping exercises, pastoralist and agropastoral communities document resource distribution, mobility routes, grazing zones, and conflict areas, producing spatial datasets that complement remote-sensing and ecological assessments. These participatory maps are not only technical outputs but social tools that foster dialogue among communities, local authorities, and researchers. Integrating gender-segregated mapping ensures that women's perspectives on resource access and seasonal labor patterns are captured. When coupled with digital dashboards or mobile applications, PGIS enhances collective decision-making, supports equitable land governance, and creates locally owned baselines for adaptive management of rangelands and livestock systems. It is essential to evaluate how digitalization may enhance not only the advancement of PGIS, but also the integration of contemporary scientific methodologies with traditional knowledge systems.

Locally emerging new practices to adapt to climate change by communities, facilitating farmer-to-farmer learning of solutions directly tailored to the local context, are being integrated in CGIAR agenda in countries like Colombia, Ethiopia, and Kenya. Key stakeholders in agroecology increasingly recognize that agroecosystem or agroecological living labs provide an effective environment for collaborative knowledge development. These settings facilitate voluntary participation and equitable decision-making among all actors, supporting the co-development and implementation of a unified vision that prioritizes sustainability, acknowledges complexity, and considers local context (McPhee et al. 2021; McPhee and Schwarz 2024).

3.9. Social values and diets

The global nutrition burden is shifting in complex ways that matter for livestock policy. Hundreds of millions of people are affected by anemia, vitamin A deficiency, and child stunting, while obesity and diet-related non-communicable diseases are rising (Popkin and Ng 2021). Animal source foods provide a small fraction of calories but a concentrated share of bioavailable iron, zinc, calcium, vitamin B12, and high-quality protein, nutrients that are often lacking in cereal-based diets and are particularly critical for infants, adolescent girls, and pregnant and lactating women (Adesogan et al. 2020).

Agroecological livestock systems could improve access to these nutrients. For infants and young children 6–23 months, global guidelines endorse regular inclusion of animal-source foods as part of safe and appropriate complementary feeding, as recognized by the World Health Organization (Adesogan et al. 2020). However, realizing these nutritional benefits requires explicit attention to affordability, equity, food safety, and prudent antimicrobial use. A One Health approach is essential to manage zoonotic diseases in livestock systems, including hygienic handling of manure and slurry is critical to protecting food safety along feed–milk–water pathways. Similarly, healthier soils and diversified forages also support legumes and leafy vegetables that broaden household diets.

In Tanzania, women's groups have pioneered improved goat management, increasing household nutrition, and income through better husbandry, market access, community-based health services, and financing empowerment through village saving and loan associations (Eik et al. 2008).

Agroecological livestock systems in LMICs contribute to improved nutritional and social outcomes by supporting culturally appropriate, nutritionally diverse, and locally grounded food systems. The erosion of traditional foods, cooking skills, and food-related knowledge has contributed to a global shift towards unhealthy diets (Rockström et al. 2025). Agroecological approaches, particularly those that promote biodiversity, offer a means to reverse this trend within food systems including livestock production.

By prioritizing indigenous knowledge, local food preferences, and regionally adapted livestock breeds, these systems align production with prevailing dietary patterns. Participatory governance that includes women and marginalized groups strengthens social cohesion and empowers stakeholders to shape their food environments. This, in turn, improves the availability, affordability, and acceptability of animal-source foods—such as milk, eggs, and meat—contributing to improved nutrition, especially for vulnerable populations like children and pregnant women.

By linking dietary goals with equity, ecological stewardship, and animal welfare, agroecological livestock systems enhance dietary diversity, food security, and celebrate cultural food heritage. Considering that livestock can utilize marginal lands unsuitable for crops, nutritional life-cycle assessments—per unit of land area, water usage, and GHG emissions—are essential to inform strategies that improve food and nutrition security and livelihoods, while reducing environmental and climate impacts.

3.10. Fairness

Integrating fairness into agroecological livestock systems in LMIC requires a holistic approach that addresses social, economic, and gender equity. Fairness is promoted by ensuring that all stakeholders—including smallholder farmers, pastoralists, women, and marginalized groups—have equitable access to resources, decision-making, and economic opportunities. This can involve participatory governance structures, such as community-led rangeland management institutions and multi-stakeholder platforms, which empower local voices in shaping management practices and policies.

Effective implementation also requires careful analysis of prevailing social norms to identify any gaps that may limit the uptake of agroecological approaches. Addressing these constraints is essential to balancing productivity, sustainability, economic growth, and social equity. Gender equity can be advanced by intentionally involving women in leadership and capacity-building, as seen in initiatives where women's participation in livestock value chains boosts both household nutrition and financial autonomy (Eik et al. 2008). Fair market access and transparent value chains further reinforce equity by ensuring producers receive just compensation for their products and labor.

Given the substantial social and ecological benefits associated with agroecological livestock systems, it is essential to advance our knowledge of market and policy innovations that can increase the value of products originating from these systems. In parallel, there is a need for practical, widely applicable metrics that enable all stakeholders in agroecological livestock systems—including herders, farmers, pastoralists, indigenous groups, local communities, and vulnerable populations—to assess system performance through an equity lens.

3.11. Connectivity

Landscape-scale planning maintains habitat corridors, supports wildlife-livestock coexistence, and fosters knowledge exchange among communities. Integrated land-use approaches can create functional mosaics that enhance biodiversity while sustaining rural livelihoods. In the Brazilian Cerrado, Integrated Crop-Livestock-Forestry (ILPF) systems combine agricultural, livestock, and forestry components to improve soil health, reduce deforestation, and mitigate GHG emissions while providing multiple income streams (Bungenstab and Giolo de Almeida 2014). These systems represent a form of sustainable intensification that increases food production by improving environmental quality. Short integration cycles, in some cases as brief as four years, enable continuous cash flow alongside long-term productivity gains. Similar diversification approaches are being implemented in Uttar Pradesh in India to strengthen rural livelihoods.

Territorial approaches to connectivity are also evident in pastoral systems. In Tunisia, Pastoral Living Landscapes (PLL) apply integrated pastoral development and rangeland restoration strategies that address both the direct and underlying drivers of rangeland degradation and marginalization. These initiatives reduce grazing pressure, strengthen rangeland governance, and enhance long-term sustainability.

Pastoralism exemplifies adaptive capacity and resilience to environmental variability (Standley 2012). However, climate change is intensifying risks from droughts, floods, heatwaves, and shifting disease vectors, threatening livestock productivity, animal health, and rural livelihoods. Many regions face new or intensified diseases, while others experience reduced pasture productivity and water resources. In some pastoral contexts, accelerating climate change can also fuel conflicts, e.g., through deteriorating livelihood conditions or changing of the historic, seasonal transhumance patterns (Van Baalen and Mobjörk 2017). Regional and cross-border cooperation can help address these challenges, particularly those related to mobility and shared resources (World Bank Group 2020).

Herd-mobility remains a critical risk management strategy, enabling access to seasonal pastures, improving animal health and welfare, and delivering ecosystem co-benefits such as nutrient recycling (i.e., animal dungs) and seed dispersal (Turner et al. 2014). While mobility strengthens landscape connectivity, it also requires coordinated efforts to prevent and manage zoonotic disease risks. Achieving One Health objectives therefore depends on effective surveillance, information sharing, and cooperation among pastoral communities, veterinary services, and public health systems (Gilbert et al. 2021).

3.12. Land and natural resources governance

Pastoralists play a critical role as stewards of rangelands. Livestock mobility enables access to spatially and seasonally variable grazing resources, while rotational grazing optimizes resource use and supports ecosystem health. Pastoralists and their livestock co-exist with wildlife including iconic mega-species at the heart of many countries' tourism. However, pastoralists face growing pressures, including rangeland loss and fragmentation, restricted mobility, climate variability, invasive species encroachment, insecurity, and conflict. These challenges are increasingly undermining their capacity to sustain healthy landscapes and productive herds.

Invasive species, such as *Prosopis juliflora*, are among the leading drivers of rangeland degradation, altering vegetation structure, reducing palatable biomass, and restricting livestock and wildlife mobility. Remote sensing and geospatial analytics now play a pivotal role in detecting, mapping, and monitoring these invasions across vast and inaccessible rangeland areas. Multi-temporal satellite data, such as Sentinel-2, PlanetScope, and radar imagery, enable early detection of spread patterns and assessment of restoration effectiveness over time. When combined with participatory rangeland management (PRM), these technologies provide actionable intelligence for communities to prioritize interventions, such as mechanical removal, reseeding with native grasses, and rotational grazing. Participatory mapping ensures that indigenous knowledge complements satellite observations, validating invasion hotspots and identifying areas of socio-ecological importance. This integration of community insight and remote sensing strengthens local governance, accelerates ecosystem recovery, and safeguards the productivity and resilience of rangelands.

Community-based planning and governance—especially in rangelands and commons—support sustainable resource use, conflict mitigation, and restoration of degraded landscapes. As part of decentralization policies for the management of natural resources, some West African countries encourage the establishment of local conventions, such as the local land charters in Burkina Faso (Vall et al. 2015).

Livestock keepers generally have an innate relationship with their land as well as their livestock. Agroecologically-principled mixed crop-livestock farmers strive for optimization of land use through an integrated system, with livestock providing draught power and manure for crops, and crop land or residues being used for feeding livestock post-harvest. Growing nitrogen-fixing crops or agroforestry forage trees in between or part of food crop systems can improve the soils, whilst also providing additional feed for livestock.

In pastoral systems with conserved biodiversity, the opportunity to combine agroecological principles and OECM criteria could provide an operational framework for land ownership and the management by pastoral communities of sustainable and biocultural diverse pastoral ecosystems (Caron et al. 2026).

Box 3: PRM for resilient livestock-based livelihood systems

PRM builds the capacity of communities in pastoral areas to better plan, manage, and govern their lands. Communities lead the process, and a rangeland management institution is strengthened or established as the responsible authority for PRM. It promotes sustainable use, management and governance of healthier rangelands, maintaining biodiversity and providing more resilient livestock-based livelihood systems. PRM was introduced to Ethiopia's pastoral regions in 2010 and initially piloted at local, village, and landscape levels. In 2015, comprehensive guidelines were developed to support PRM mapping activities and a review in 2019 underscored the program's early positive impacts and its potential to enhance governance, rangeland health, productivity, conflict reduction, and community well-being. Building on these outcomes, a European Union-funded initiative—executed by local NGOs in partnership with the International Land Coalition—expanded PRM implementation to Kenya and Tanzania.

In 2020, ILRI and Kenyan county governments, developed a PRM toolkit that led to measurable improvements in rangeland management, livestock productivity, and women's involvement, as confirmed by a 2021 evaluation. The approach has since been integrated into wider development programs, including One Health and peacebuilding efforts, but ongoing promotion of PRM principles remains necessary, especially regarding gender equity, conflict resolution, and policy support. Backed by the CGIAR science program on multifunctional landscapes, PRM is now active across over one million hectares in Ethiopia, Kenya, and Tanzania, with plans for further expansion.

As noted by Freed et al. (2025), it is essential that water receives significant emphasis within agroecological principles, given its vital importance for productivity, sustainability, and livelihoods. We recommend that water stewardship within livestock systems be incorporated into the land and natural resources governance principle of agroecology. Nonpoint source pollution from conventional livestock systems is a major challenge across many regions, adversely affecting freshwater ecosystems. The resulting decline in water quality reduces the quantity of usable water, resulting in water scarcity problems (Organisation for Economic Co-operation and Development [OECD] 2017). Agroecological livestock systems emphasize water conservation and management, including restoration of degraded lands and wetlands, construction of water conservation structures, and planned grazing to reduce erosion and enhance infiltration.

In the Sahel, community-managed grazing and water-spreading bunds have revived pasture productivity and water tables (World Bank Group 2021). More than 300 producers in the department of Caquetá in Colombia are implementing a water harvesting strategy that will allow them to be prepared for future droughts, improving their livestock productivity and conserving watersheds. These producers are already seeing the benefits and are inspiring others to implement a series of adaptation strategies to climate variability. In Maharashtra, India, hydrology-based landscape management approach for groundwater recharge contributes to sustainable livestock and farming systems, reducing water, energy, and carbon footprint.

In South Asia, studies led by the International Water Management Institute (IWMI) show that improvements in Livestock Water Productivity (LWP) through better feed–water linkages, water-efficient fodder systems, and managed drinking-water sources substantially reduce the total water footprint of mixed crop–livestock systems (Amede et al. 2011; Drastig et al. 2021). Agroecological livestock management practices that enhance soil organic carbon also improve soil moisture retention, thereby lowering irrigation demand for fodder and food crops (Palm et al. 2014; Praharaj et al. 2025). In several Indian states, including Andhra Pradesh and Madhya Pradesh, integrating rainwater harvesting with livestock-centered nutrient recycling has strengthened on-farm water-use efficiency and resilience to dry spells (FAO 2020; Garg et al. 2022). Together, these approaches illustrate how water stewardship in livestock systems can serve as a key lever for climate adaptation and sustainable intensification under Indian conditions and beyond. This prompts an assessment of how agroecological strategies may improve climate adaptation and mitigation by utilizing ecosystem-based methodologies.

3.13. Participation

Participation is not only paramount for land and natural resources governance in livestock systems, but it is equally critical across all the agroecological principles. It is a key determinant of success or failure of most livestock systems. Participatory approaches engage diverse stakeholders—women, youth, indigenous peoples—in co-designing livestock interventions, ensuring context-specific solutions, and equitable benefit distribution (Caron et al. 2022). Such approaches enhance adaptive management and empower marginalized groups, ensuring that outcomes benefit communities and the environment (Scoones and Thompson 2009). Livestock, particularly poultry and small ruminants, is also one of the main assets accessible by women.

Strengthening women's agency and decision-making power, while actively engaging men, is instrumental for success in participatory processes (FAO 2024). Convening multi-stakeholders' platforms or communities of practices that enable knowledge and experience sharing on issues like climate change adaptation and mitigation empower farmers, pastoralists, fishermen, and other food system actors. The approach is crucial to develop a shared vision and action plans to achieve the vision, leaving none behind.

In Mongolia, the government and herder communities are establishing herder associations, such as pasture user groups (PUGs), to collaboratively manage communal pastures by setting rules for livestock use, thereby balancing herd sizes with the health and carrying capacity of the rangelands (Ulambayar and Fernandez-Gimenez 2019). This is a response to increased rangeland degradation from a surge in livestock numbers after the 1990s, especially small ruminants, which intensified grazing pressure. The new approaches involve formalizing pasture use rights, implementing community-based rangeland management, and integrating traditional ecological knowledge[1] with formal monitoring to promote sustainable practices and mitigate the impacts of climate change and land degradation. The herder associations in Mongolia oversee the community-based management, formalizing rights and responsibilities, balancing livestock with capacity, integrating traditional knowledge, seek policy and legislative support, address environmental challenges through promotion of sustainable practices, and foster collaboration and partnerships. PRM, promoting biodiversity through integrating productive grazing areas and shrubs for browsers often results in improved livestock productivity and health, while boosting economic outcomes, enhancing soil health and resilience to climate change impacts, and reducing resource conflicts among neighboring communities.

[1] Traditional ecological knowledge is a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings with one another and with their environment.

4. Synergies and trade-offs among agroecological principles

The relevance of agroecological livestock systems is increasingly recognized amid the need for resilient food systems that balance productivity, sustainability, economic viability, and social inclusion while preserving biocultural diverse ecosystems. When effectively applied, agroecological approaches create synergies that enhance productivity, sustainability, economic opportunities, and social inclusion. However, these benefits are often accompanied by trade-offs that must be carefully managed through participatory processes, supportive policies, and adaptive management. Balancing these dynamics is essential for achieving resilient, equitable, and sustainable livestock systems that meet the needs of both people and the planet. Further research is needed on effective scaling models to maximize synergies and minimize trade-offs.

4.1. Synergies

Agroecological principles tend to reinforce one another when applied in integrated livestock systems. For instance, promoting biodiversity through diversified crop-livestock-forestry mosaics creates habitats that support both wildlife and livestock, strengthening ecological connectivity across landscapes (Fynn et al. 2016). This connectivity facilitates ecosystem services such as pollination, pest control, and nutrient cycling, which underpin system resilience and productivity. Healthy soils are instrumental for animal health and welfare as they impact forage productivity and nutritional quality, while reducing soilborne diseases.

Participatory knowledge creation, involving pastoralists, researchers, and policymakers, further amplifies these synergies by incorporating local and scientific perspectives into management decisions. This inclusiveness leads to context-specific innovations—such as community-managed grazing and water conservation structures—that enhance water stewardship and resource use efficiency. When gender-segregated mapping and digital tools are employed, the collective decision-making process becomes more equitable and adaptive, fostering social cohesion and more sustainable resource governance.

4.2. Trade-offs in practice

Despite these benefits, trade-offs are inherent in agroecological livestock systems. Balancing short-term productivity with long-term ecological health is a major challenge. For example, restoring degraded rangelands or implementing planned grazing may temporarily reduce livestock output while improving soil and water resources over time. Similarly, using crop and forage residues for livestock feed benefits animal nutrition but may deplete soil nutrients and organic carbon if manure is not returned to the fields (Duncan et al. 2016).

Co-existence of livestock and wildlife enhances biodiversity and ecosystem functions but can increase zoonotic disease risks, herbivore competition, and predations pressures. Addressing these challenges necessitates effective management strategies for livestock and ecosystems, including zoning and land use planning, to achieve an appropriate balance (Barroso and Gortázar 2024). Similarly, the integration of ecological corridors for biodiversity conservation, which considers migrating species (Ding et al. 2023), may restrict land available for intensive production and other land-based commercial activities, potentially impacting short-term economic returns.

Participatory approaches, while empowering, can slow decision-making and require investments in training and facilitation. Moreover, efforts to ensure social inclusion—such as addressing gender norms or land tenure insecurity—may encounter resistance from entrenched interests, potentially delaying broader adoption of agroecological practices. Such socio-ecological trade-offs require further investigation to balance productivity, sustainability, economic development and socio-equity.

4.3. Implications for productivity

The interplay of synergies and trade-offs shapes productivity outcomes in agroecological livestock systems. While diversified systems may initially yield lower outputs compared to high-input, specialized operations, they often demonstrate greater resilience to shocks such as droughts or market fluctuations. Practices like water harvesting and integrated land use have been shown to stabilize or enhance productivity, particularly in marginal environments, by improving resource availability and reducing vulnerability to climate extremes. Adaptive management, supported by participatory knowledge systems, ensures that innovations are tailored to local conditions, enhancing their effectiveness and adoption.

4.4. Implications for sustainability

Agroecological principles deliver significant environmental benefits, including improved soil health, reduced deforestation, enhanced carbon sequestration, and better water management. These outcomes contribute to long-term sustainability by maintaining ecosystem functions and supporting climate resilience. However, achieving these benefits may require trade-offs in the form of reduced immediate yields or the need for substantial initial investments in capacity-building and infrastructure. The success of sustainability measures depends on the ability to integrate ecological, social, and economic objectives within landscape-scale planning.

4.5. Economic opportunities

Economic diversification is a hallmark of agroecological livestock systems. By producing a range of outputs—such as meat, milk, timber, and ecosystem services—farmers and pastoralists can buffer against market volatility and climatic risks. Access to new markets, particularly those that value sustainable or differentiated products, offers additional income streams. However, dominant value chains and policy environments often favor conventional, large-scale production, creating barriers to market access for agroecological producers. Overcoming these challenges requires supportive policies, investment in value-added processing, and the development of alternative market channels.

4.6. Social inclusion and biocultural diversity

Participatory approaches and inclusive governance structures are central to realizing the social benefits of agroecological transitions. By engaging marginalized groups, women, and youth in decision-making, these systems foster empowerment, knowledge exchange, and equitable access to resources. Gender-sensitive mapping and capacity-building initiatives ensure that diverse perspectives inform management practices, promoting social cohesion and adaptive capacity. Nevertheless, overcoming social norms and power imbalances remains an ongoing challenge, requiring sustained commitment and institutional support.

Agroecological principles within livestock systems play a critical role in preserving pastoral environments and cultural traditions that have evolved and become interdependent over time yet currently face challenges from global forces such as the industrialization of animal agriculture. These principles are essential for sustaining and promoting biodiversity in rangelands and supporting pastoral livelihoods.

5. Recommendations and implementation considerations

5.1. Key actions to advance agroecological livestock systems

- **Policy alignment**: Integrate principles, including in efficiency, resilience, equity, and biodiversity, across agricultural, livestock, and environmental policies.
- **Support local innovation**: Promote initiatives, local innovation, and knowledge-sharing platforms led by farmers, herders, pastoral societies, indigenous people, and local communities.
- **Capacity building**: Strengthen local organizations—including women's groups and producer associations—for inclusive governance.
- **Gender and social inclusion**: Apply gender analysis and inclusion metrics throughout project planning and monitoring.
- **Research and evidence**: Invest in participatory research and long-term ecological studies to strengthen evidence for agroecology.
- **Market development**: Improve market access through infrastructure, certification, and business models that value sustainable production.
- **Financial incentives**: Develop financial mechanisms such as ecosystem service payments, climate insurance, and green credit lines to incentivize regenerative practices.
- **International collaboration**: Foster international collaboration through knowledge networks and policy exchanges.

5.2. Implementation considerations

- **Inclusive stakeholder engagement**: Involve farmers, herders, pastoralists, pastoral societies, researchers, and policymakers in participatory decision-making and vision setting.
- **Context-specific adaptation**: Tailor interventions to local ecological, economic, and social contexts using tools like mapping and scenario planning.
- **Adaptive management**: Apply flexible management approaches that incorporate ongoing monitoring, peer learning, and iterative adjustments to respond to changing conditions.
- **Financial and risk support**: Provide public and private finance, innovative instruments, and risk management tools to support transitions and buffer shocks.
- **Conflict resolution and inclusion**: Address disputes and promote equity through participatory planning, mediation, and equitable benefit-sharing.
- **Monitoring and evaluation**: Establish clear, actionable metrics for environmental, social, and economic impacts. Use participatory evaluation to enhance relevance, community ownership, and accountability.

6. Case studies of livestock systems integrating selected agroecological principles

Case study 1: The Maasai of Kenya and Tanzania (Omondi et al. 2021)

The Maasai have long practiced mobile pastoralism, adjusting herd movements seasonally to optimize pasture use and reduce pressure on any one area. Recent participatory projects have supported Maasai communities to map grazing lands, co-manage wildlife-livestock interfaces, and restore degraded rangelands using indigenous knowledge and modern science. These efforts have improved grassland health, wildlife populations, and community resilience.

Credit: @Shutterstock

Case study 2: Dairy cooperatives in India (Dervillé et al. 2023)

The India dairy revolution, anchored in cooperative models, has enabled millions of smallholders—many of them women—to access credit, technical support, and markets. Agroecological principles are now being integrated into cooperative extension, including improved breed selection, pasture management, and manure recycling. Complementary initiatives in states such as Andhra Pradesh, Gujarat and Madhya Pradesh further embed livestock within community-managed natural farming, promoting locally adapted fodder systems, on-farm nutrient cycling, and reduction in chemical inputs—illustrating agroecology in action through social mobilization and local resource stewardship.

Credit: @Shutterstock

Case study 3: Silvopastoral systems in Latin America (Mauricio et al. 2019; Sandoval et al. 2023; Picasso and Pizarro 2024)

In Colombia, Nicaragua, and Brazil, silvopastoral systems integrate trees, pasture, and livestock, increasing productivity and resilience while enhancing biodiversity and carbon stocks. Initiatives supported by governments and NGOs provide training, seedlings, and payments for ecosystem services, demonstrating the economic and ecological benefits of diversification.

Credit: @Shutterstock

Case study 4: Community rangeland management in Mongolia (Addison et al. 2013; Ulambayar and Fernández-Giménez 2019)

Herder groups in Mongolia have formed pasture user associations, jointly planning grazing rotations and investing in restoration of degraded lands. These collective actions, backed by legal recognition of common property, have improved rangeland conditions, reduced conflicts, and strengthened social capital.

Credit: @Shutterstock

Case study 5: Finding solutions within adaptation pioneers in the Ethiopian highlands (Habermann et al. 2025)

Pioneer-Positive Deviance identifies adaptation pioneers using unconventional, effective practices for sustainable and profitable farming systems. In Ethiopia's Highlands, 34 local innovators were studied, with four pioneers tracked for sheep management and peer to peer field days. Adaptation pioneers share uncommon, affordable feeding practices using their own resources avoiding risks and increasing farm income through sustainable livestock. This empowered self-recognition, knowledge-sharing, and mutual learning, transforming pioneers into community facilitators and highlighting farmer-led innovation for climate adaptation.

Credit: @M.Spinelli, ILRI

Case study 6: Smallholder pasture management and biodiversity in the Kenyan highlands (Onyango et al. 2025)

The HABITAT project examines how agroecological practices, such as diverse forage planting, rotational grazing, and integrated tree-livestock systems, used by smallholder dairy farmers in Kenya's highlands enhance biodiversity, soil health, and climate resilience. By studying farmer-led innovations of adaptation pioneer families/households and trade-offs between productivity and sustainability, the project aims to scale up agroecological pasture management for broader regional impact.

Credit: @ILRI

Case study 7: Promoting sustainable agro-pastoral livelihoods in transfrontier conservation areas in southern Africa (Caron et al. 2022)

The ProSuLi project used a fully participatory approach, i.e., project activities were not defined in the proposal but co-designed by local stakeholders to promote sustainable livelihoods for four local agropastoral communities living in the periphery of protected areas in Botswana, Zimbabwe, and Mozambique. With the aim to promote healthy ecosystems with healthy people and healthy wild and domestic animals, interventions were designed, implemented, and monitored by local stakeholders through an in-depth participatory process. With the sustainability of the interventions as one of the key goals of the interventions, five years after the end of the project, the ProSuLi community will soon assess the impact of the project.

Credit: @A. Caron, CIRAD

Case study 8: Managing animal diseases at wildlife-livestock interface in agropastoral systems (de Garine-Wichatitsky et al. 2021)

At the wildlife-livestock-human interface, disease transmission can trigger conflicts that threaten the fragile coexistence between people and nature. Pathogen spillover from wildlife to cattle or human—and vice versa—represents a significant challenge to both health and coexistence. Effective management requires agropastoralists' indigenous knowledge and more modern veterinary and ecological sciences. Over more than a decade of research in southern Africa, interventions targeting the wildlife-livestock-human interface have been shown to mitigate sanitary risks while reducing broader human-wildlife conflicts. These approaches highlight the importance of combining local expertise with scientific monitoring and adaptive management to safeguard both livelihoods and biodiversity in agropastoral landscapes.

Credit: @B. Faye, CIRAD

Case study 9: Integrated farming systems and water stewardship in India (ICAR-IIFSR 2023; Kumar et al. 2025)

Integrated Farming Systems (IFS) in India demonstrate how agroecological design can enhance water stewardship by linking crops, livestock, aquaculture, and trees in mutually reinforcing nutrient and water cycles. Across Karnataka, Andhra Pradesh, and Odisha, IFS farmers channel harvested rainwater into farm ponds, percolation tanks, and on-farm reservoirs that provide reliable drinking water for livestock while supporting fish culture. Livestock manure is applied to pond systems to promote plankton growth, and nutrient-rich silt from desilted ponds is recycled back to fields as organic fertilizer. Continuous application of organic amendments improves soil organic carbon and increases soil moisture retention, reducing irrigation needs by as much as 30–50% in several documented IFS models. Year-round fodder availability, diversified income streams, and improved drought resilience have made IFS a cornerstone of climate-smart agriculture programs promoted by ICAR and State Agricultural Universities. These systems embody agroecological water stewardship by creating closed-loop, resource-efficient landscapes that buffer farm households against climatic shocks while enhancing long-term soil and water productivity.

Credit: @Shutterstock

Case study 10: Soil health benefits of Brachiaria forage systems (Byrnes et al. 2017; Notenbaert et al. 2021)

Brachiaria-based forage systems provide a compelling example of how cultivated forages can transform soil health in mixed crop–livestock systems. Chemically, Brachiaria improves soil fertility through root exudates and high-quality biomass that stimulate nutrient cycling, enhance microbial activity, and increase soil carbon stocks and long-term sequestration. Several Brachiaria cultivars are also known for their capacity to inhibit biological nitrification, reducing nitrogen losses and strengthening the soil's role in climate change mitigation.

Physically, Brachiaria's dense root system improve soil structure, aggregation, aeration, and water-holding capacity, while its persistent root residues and ground-covering growth reduce soil erosion and surface compaction. Biologically, Brachiaria promotes diverse and active soil biota. Its deep and fibrous root architecture stimulates microbial communities across soil horizons, supporting processes essential for nutrient transformation and carbon stabilization. When integrated with other compatible forage species or tree-based fodder systems, Brachiaria helps create conditions that favor richer mycorrhizal networks and more resilient soil ecosystems. Taken together, Brachiaria forage systems demonstrate how strategic integration of improved forages can deliver multi-dimensional soil health gains while contributing to more productive, sustainable, and climate-smart livestock systems.

Credit: @Shutterstock

7. Analysis: Barriers, enablers, and evidence

7.1. Barriers to agroecological transition

Despite the promise of agroecological livestock systems, several barriers impede widespread adoption:

- **Policy and institutional inertia**: Many agricultural policies, subsidies, and research agendas favor input-intensive, large-scale livestock production, undermining agroecological alternatives despite global guidance urging nutrition-sensitive, agroecological policy alignment and participatory monitoring.
- **Market pressures and value chains**: Dominant value chains prioritize uniformity, scale, and short-term returns, often excluding smallholders and agroecological products from lucrative markets.
- **Knowledge gaps and extension services**: Limited access to information, training, and participatory research hampers the dissemination and local adaptation of agroecological practices.
- **Land tenure insecurity**: Unclear or contested land rights either on common or private lands, especially among pastoralists, women, and marginalized groups, inhibit investments in sustainable land management.
- **Climate and environmental risks**: Climate variability and extreme events create uncertainty, discouraging long-term investments in agroecological transition.
- **Social norms and power dynamics**: Gender norms, traditional hierarchies, and lack of representation can exclude women, youth, and indigenous peoples from decision-making.
- **Economic concerns**: While farmers recognize the added value of agroecology for the environment (Coe et al. 2025), many question its economic viability (Orounladji et al. 2024).

7.2. Enablers for agroecological transition

Key enabling factors can overcome these barriers and support the transition:

- **Supportive policy frameworks**: Integrating agroecological principles into national strategies, subsidies, and extension services, aligning incentives and resources.
- **Market innovation and certification**: Development of value chains for agroecological products, participatory guarantee systems, and inclusive cooperatives can reward sustainable practices.
- **Knowledge co-creation and extension**: Combine traditional knowledge and modern science, through multistakeholder platforms, farmer field schools, participatory research, and exchange visits to foster peer learning and adaptation to local contexts (ElDidi et al. 2025; Vall et al. 2025).
- **Secure land rights**: Legal recognition of communal and individual tenure underpins sustainable management and investment.
- **Climate resilience tools**: Early warning systems, climate insurance, and adaptive management empower communities to cope with shocks.
- **Gender and social inclusion initiatives**: Targeted programs for women's empowerment, youth engagement, and inclusion of marginalized groups broaden participation and equity.

Box 4: India leads the way: Livestock-integrated agroecology for sustainable farming

In the Global South, several national and subnational programs are institutionalizing agroecological principles through policy and funding support. India's *National Mission on Natural Farming (NMNF)* and *Paramparagat Krishi Vikas Yojana (PKVY)* explicitly promote chemical-free agriculture based on livestock-derived inputs, on-farm nutrient recycling, and integrated farming. State-led initiatives, such as *Community-Managed Natural Farming (CMNF)* in Andhra Pradesh and *Gujarat Natural Farming Programme*, have demonstrated scalable models where livestock integration underpins soil health regeneration, reduction in input costs, and improved farm incomes. Similar policy efforts in countries such as Bhutan, Nepal, and Sri Lanka emphasize organic and livestock-linked systems, highlighting a wider regional momentum toward agroecological transformation.

7.3. Evidence base and performance assessment

Robust, context-sensitive evidence is essential for tracking progress, informing policy, and scaling agroecological livestock systems. Key indicators include:

- Soil health (e.g., organic carbon, aggregate stability, nutrient cycling efficiency etc.)
- Biodiversity (species richness, habitat connectivity, pollinator abundance etc.)
- Water use and quality (infiltration rates, watershed condition etc.)
- Emission intensities
- Economic indices (income diversification, productivity, input costs, financial viability or value cost ratio, market access etc.) (Alary et al. 2011; Alary et al. 2022)
- Social inclusion (stakeholder participation, gender equity metrics, youth involvement etc.)
- Animal welfare (disease incidence, longevity, pasture access etc.)
- Diet quality and intake (Minimum Dietary Diversity for Women, proportion of children 6–23 months meeting WHO/UNICEF complementary-feeding indicators such as Minimum Acceptable Diet, and frequency of consumption of milk and eggs by women, adolescent girls, and young children)
- Nutrition efficiency (Micronutrient-based functional units that report absorbable iron, zinc, calcium, vitamin B12, or high-quality protein delivered to local diets per unit land, water, and greenhouse gas etc.)
- Food safety (Milk and meat hygiene measures such as total plate counts and somatic cell counts, aflatoxin M1 in milk where relevant, and antimicrobial residues; share of value chains using quality-based milk payment or Hazard Analysis and Critical Control Point (HACCP)-like controls)
- Antimicrobial resistance stewardship (Farm-level antimicrobial use tracking and participation in surveillance systems)

Long-term, participatory monitoring, integrated with farmer, herder, and community knowledge, eases adaptive management and continuous improvement.

8. Policy options to reduce barriers and enhance enablers

Agroecology is a context-responsive yet conceptually coherent approach whose discursive diversity provides empirical grounding for flexible, co-produced policy translation across ecological and social settings (Madsen et al. 2025). In Africa, agroecological transformation is both a technical and discursive process, framed by three narratives:

1. **"Tool in the toolbox"** – Agroecology as a set of practices that can be selectively integrated into conventional industrial agriculture.
2. **Coping strategy** – Agroecology as an approach for resource-poor farmers lacking access to modern inputs and technologies.
3. **A transformative paradigm** – Agroecology as a holistic, just, and sustainable alternative to industrial food systems.

Each of these framings entails distinct policy orientations: when agroecology is reduced to a "low-input" or "poverty alleviation" strategy, its systemic and transformative dimensions risk being marginalized. The analysis underscores the necessity of narrative literacy among policymakers, who must critically engage with and navigate these competing discourses to design coherent and equitable agroecological strategies. Consistent with the call by Madsen et al. (2025) for knowledge co-creation, integrating narrative analysis into policy processes facilitates a shift beyond technocratic interventions toward a socially embedded, inclusive, and reflexive vision of agroecological transformation. Below are a few policy options that could contribute to accelerating agroecology in livestock systems.

8.1. Promote resource-efficient livestock practices

Implementing resource-efficient practices is essential for the sustainability of livestock systems. Supporting on-farm nutrient recycling through effective manure management, composting, and biogas generation helps optimize resource use and minimize waste. Facilitating the transition to pasture-based feeding, multispecies grazing, and maintaining optimal stocking densities promotes both animal health and environmental stewardship. Encouraging diversification by integrating livestock production with crop cultivation and agroforestry further enhances resource efficiency and ecological resilience.

8.2. Enhance resilience and land stewardship

Building resilient livestock systems requires incentives for rotational, planned, and adaptive grazing methods. Funding should be directed toward the restoration of wetlands and forests, conservation of watersheds, and the establishment of soil conservation structures. Supporting landscape-scale planning and rangeland rehabilitation helps maintain ecosystem services and fosters sustainable land stewardship across agricultural landscapes. Utilizing human-inedible biomass as animal feed and producing feed on low-opportunity lands can enhance overall nutritional efficiency within production systems. Additionally, establishing forage reserves, implementing water harvesting strategies, and providing local chilling facilities are critical for ensuring the safe availability of milk and eggs during periods of scarcity.

8.3. Advance animal health and welfare

Establishing clear standards for animal welfare is vital, including requirements for pasture access, low-stress management practices, and reduced reliance on antibiotics. In addition, research and extension services should be promoted to support diverse diets, disease prevention strategies, and the use of resilient livestock breeds, thereby improving the overall health, productivity, and longevity of animals within agroecological systems. The integration of feed-safety controls and testing is essential for minimizing contamination by pathogens such as aflatoxin, thereby reducing the risk of carry-over into milk and other animal-derived foods. Accordingly, harmonizing national policies with CFS recommendations that connect agroecology, healthy diets, food safety, and antimicrobial resistance (AMR) stewardship is fundamental to advancing the principles of One Health.

8.4. Foster economic diversification and circular economies

Facilitating value chains for a range of livestock products—such as milk, meat, manure, fiber, and labor—supports economic diversification and strengthens rural livelihoods. Supporting rural employment and innovative business models that integrate various production systems encourage circular economies. Developing markets for ecosystem services, including carbon sequestration, watershed management, and nutrient management, as well as biodiversity conservation, further enhances the economic viability of agroecological practices.

8.5. Secure social equity and participatory governance

Institutionalizing participatory land-use planning, rangeland governance, and resource-sharing mechanisms ensures inclusive decision-making. Integrating gender inclusion and fair labor practices into livestock policies and programs promotes equity within agricultural communities. Facilitating access to resources and inclusion in decision-making processes for marginalized groups is essential to achieve effective agroecological transformation. Enhancing women's authority over micro-revenues derived from milk, eggs, and small ruminants aligns with CFS guidance and serves as a strategic approach to improving household dietary quality and equitable benefit sharing.

8.6. Incentivize performance monitoring and adaptive management

Mandating the use of agroecological performance indicators in policy monitoring enables the ongoing assessment of outcomes and progress. Investing in research networks and encouraging data sharing fosters evidence-based learning and supports the adaptive management necessary for continuous improvement in livestock systems.

9. Future directions and research gaps

While agroecological livestock systems offer immense potential, several research gaps and emerging areas deserve further attention:

- **Integration of technology and traditional knowledge**: How can digital tools (sensors, data platforms, remote sensing) complement indigenous and local knowledge for adaptive management?
- **Socio-ecological trade-offs**: How do different agroecological strategies balance productivity, biodiversity, and equity under diverse contexts?
- **Scaling models and incentive structures**: What are the most effective models (cooperatives, networks, public-private partnerships) for scaling innovations?
- **Climate resilience and risk**: How can agroecological systems buffer against, and adapt to, increasing climate variability and extreme events?
- **Market and policy innovations**: How can certification, traceability, and market-based incentives drive demand for agroecological livestock products?
- **Equity and inclusion metrics**: Which metrics best capture progress in gender equity, social inclusion, and benefit-sharing?
- **Nutrition efficiency**: How can nutritional life-cycle assessment, using micronutrient-based functional units (e.g., mg absorbable iron or vitamin B12 delivered per hectare, per m^3 water, and per kg CO_2-e), be operationalized to guide placement on low-opportunity lands and track diet quality outcomes?

10. Conclusions

Agroecology in livestock systems offers a pathway to sustainable, resilient, equitable, and nutrition-sensitive food systems—balancing productivity with environmental stewardship. By embracing socio-ecological principles, valuing local and indigenous knowledge, and fostering inclusive governance, these systems can regenerate landscapes, empower rural actors, and deliver lasting benefits for people and nature alike.

The transition requires vision, coordinated policies, investment in research and capacity, and mobilization of social movements and global cooperation. With bold leadership, participatory action, and commitment to just transition, agroecological livestock systems can secure safe, nutritious food and livelihoods for current and future generations, laying groundwork for a thriving planet and healthy people.

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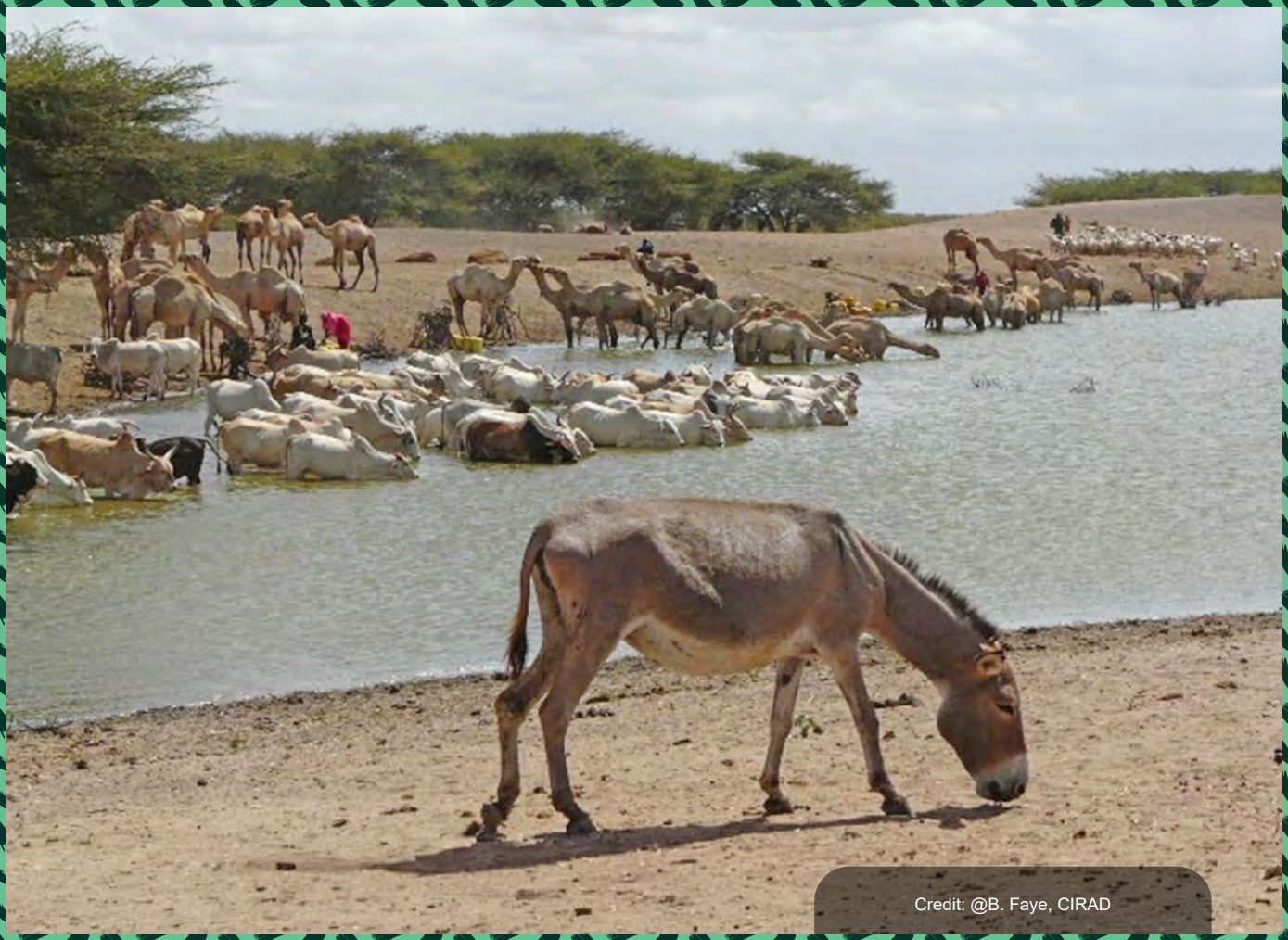

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MULTIFUNCTIONAL LANDSCAPES