Community-Based Climate Resilience: The Strategic Role of Indigenous Livestock and Poultry in Sustaining Rural Livelihoods in Sub-Saharan Africa

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Abstract
Sub-Saharan Africa hosts a rich diversity of indigenous livestock and poultry breeds that underpin rural livelihoods in the face of escalating climate challenges. These animal genetic resources are indispensable for food and nutritional security and play a critical role in enhancing the socioeconomic and ecological resilience of rural communities, particularly those that rely on smallholder agriculture. However, climate change increasingly threatens the sustainability of these systems, marked by erratic rainfall patterns, prolonged droughts, elevated temperatures, dwindling feed and water supplies, and the proliferation of new diseases and parasites. In response, rural households have adopted a range of adaptive strategies to bolster their resilience and sustain livestock productivity. These include the conservation and promotion of indigenous breeds, diversification of livestock species, integration of crop-livestock systems, adoption of micro-livestock, and implementation of fodder preservation techniques. The capacity of households to absorb, adapt to, and recover from climate-induced shocks, collectively referred to as resilience, is central to the sustainability of indigenous animal husbandry in the region. This study explores the spectrum of climate risks confronting smallholder farmers and examines grassroots adaptation strategies. This underscores the pressing need for climate-resilient livestock systems, genetic improvement of robust indigenous breeds, and the formulation of supportive policies aimed at safeguarding and strengthening local livestock and poultry production in the region.

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1. Introduction

Climate change is profoundly disrupting ecological systems, with particularly severe consequences in sub-Saharan Africa (SSA), where rural, resource-constrained communities rely heavily on agriculture for their livelihood. Indigenous livestock and poultry production systems are increasingly threatened by rising temperatures, erratic rainfall patterns, extended droughts, and a surge in climate-sensitive diseases and parasites (Slayi & Tyasi, 2022; Mhlangabezi *et al*., 2024) [69, 43]. These impacts disproportionately affect rural populations with limited access to the financial, technological, and institutional resources required for high-cost adaptive interventions. Agriculture remains the economic backbone of rural SSA, supporting nearly two-thirds of the population, with approximately 70% of households directly dependent on livestock and poultry, primarily indigenous breeds (Frontiers Partnerships, 2025; Food Systems Journal, 2025) [27, 25]. Although these breeds are inherently more resilient to harsh environmental conditions, they are increasingly burdened by land degradation, water scarcity, and a growing prevalence of infectious diseases (Nature, 2024) [55].

The complex interplay between climate variability, animal health, and rural livelihoods amplifies the vulnerability of indigenous livestock systems. Shifting precipitation regimes and escalating temperatures diminish the availability of forage and water, while simultaneously creating favorable conditions for the spread of pathogens. These dynamics compromise livestock productivity and undermine food security and income. In response, smallholder farmers employ a suite of low-cost, context-specific adaptation strategies to enhance resilience. Common responses include the conservation of indigenous genetic resources, integration of crop–livestock systems, and diversification through the inclusion of hardier species, particularly goats, which are increasingly recognized as climate-resilient assets (Assan, 2023; Frontiers Partnerships, 2025) [68, 27].

Goats exhibit key adaptive traits, such as efficient feed utilization, low water requirements, and relative resistance to diseases, making them particularly well-suited to climate-stressed environments (Frontiers Partnerships, 2025; Nature, 2024) [27, 55]. The application of resilience thinking, which focuses on enhancing adaptive capacity while reducing exposure and vulnerability (Adger *et al*., 2009) [2], offers a strategic framework for safeguarding rural livelihoods, preserving indigenous livestock biodiversity and advancing ecological sustainability. This study investigates the evolving nexus between climate change and indigenous livestock systems in SSA, emphasizing household-level adaptation strategies among resource-poor farmers and their contributions to long-term resilience amid intensifying climate risks.

2. Climate Risk Threats to Indigenous Livestock and Poultry

Smallholder farmers in Sub-Saharan Africa (SSA) are increasingly confronted with climate-induced stressors, including rising temperatures, unpredictable rainfall patterns and persistent water scarcity (Maluleke & Mokwena, 2025) [39]. These conditions contribute to forage deficits, thermal stress, and an increase in disease and parasitic infections, all of which compromise livestock productivity and threaten rural livelihoods (Adger, 2003; Nardone *et al*., 2010) [1, 52]. Indigenous livestock and poultry remain integral to rural agrarian economies across the region, providing essential assets that enable communities to buffer and adapt to climate-related shocks and stressors. In the face of escalating climate threats, smallholder farmers are deploying a range of resilience-enhancing strategies aimed at sustaining indigenous animal production at the household level, including agricultural resilience, which has emerged as a critical development paradigm, with local actors adopting diverse coping mechanisms to navigate climate variability and associated risks (Dube *et al*., 2023; Opio *et al*., 2021) [17, 63].

Figure 1 presents a conceptual framework that illustrates the multifaceted relationship between climate risk, household coping strategies, and the promotion of climate-resilient indigenous livestock and poultry systems. It highlights the cascading effects of climate-induced pressures on animal production systems and their broader implications for the socioeconomic and ecological services provided by these animals. Indigenous breeds contribute significantly to food security, income generation, employment, and nutritional outcomes, particularly for women and children, in rural communities.

Nevertheless, these systems are inherently resource-intensive, demanding considerable land, water, and biomass, which renders them particularly vulnerable to the impacts of climate change (Mwango *et al*., 2023; Gwitira *et al*., 2021) [49, 30].

The primary challenge facing indigenous livestock and poultry production lies in the direct and indirect effects of climate change, which undermine the health and productivity of animals. Altered temperature regimes, fluctuating humidity levels, and increased wind variability negatively affect reproductive performance and general productivity (Nyoni *et al*., 2021; Kassie *et al*., 2022) [61, 34]. Concurrently, shifts in rainfall patterns and ecosystem dynamics compromise the quantity and quality of feed resources, facilitating the proliferation of climate-sensitive diseases and parasites (Nhemachena *et al*., 2020; Balarabe *et al*., 2023; FAO, 2024) [57, 8, 23]. Erratic precipitation exacerbates the spread of vector-borne diseases, particularly among ruminants such as goats, sheep, and cattle, by degrading pasture quality and reducing grazing land availability (Mutambara *et al*., 2022) [46].

In this context, Indigenous Climate-Smart Livestock and Poultry Systems (ICSLPS) have gained prominence as a promising pathway for transforming subsistence livestock production. These systems prioritize resilience, productivity, and sustainability to safeguard food and nutrition security for vulnerable rural populations (FAO, 2021) [21]. ICSLPS are rooted in locally adapted, low-cost strategies such as improved husbandry practices, genetic conservation of resilient breeds, strategic water use, and forage preservation (Amole *et al*., 2024) [5]. Visible manifestations of climate change, including prolonged droughts, ecological shifts, and emerging disease patterns, underscore the urgent need to support adaptive innovations. Studies have documented declines in livestock productivity due to compromised water access and increased evapotranspiration, which further constrain livestock productivity (Mekonnen *et al*., 2021) [42]. Consequently, many farmers are shifting toward smaller drought-tolerant species such as goats and sheep, which are better suited to arid and semi-arid environments (Kassie *et al*., 2022) [34].

Water availability remains a critical determinant of livestock health and productivity; however, it is increasingly threatened by changing hydrological cycles due to climate change. Climate variability affects surface water levels, the timing and intensity of rainfall events, and the reliability of livestock watering sources, ultimately disrupting the seasonal grazing patterns. In parallel, feed scarcity, driven by climate-induced rangeland degradation and shifts in forage composition, continues to diminish the nutritional quality of available biomass (Dossa *et al*., 2021) [16]. Disease outbreaks and parasitic infestations, often aggravated by climate fluctuations, further compromise animal health and exacerbate rural food and nutritional insecurity (Opio *et al*., 2021) [63].

Diversifying indigenous livestock and poultry portfolios offers a viable resilience strategy, enabling smallholders to manage risks and improve their adaptive capacities. By adopting climate-smart technologies and practices such as selective breeding for resilience, improved feeding regimes, and rotational grazing, rural communities can mitigate climate-related disruptions (Mutambara *et al*., 2022) [46]. The continued reliance on indigenous breeds reflects the embedded adaptive potential of these traditional systems. However, growing climate pressures necessitate external support for the co-development and scaling of resilient models.

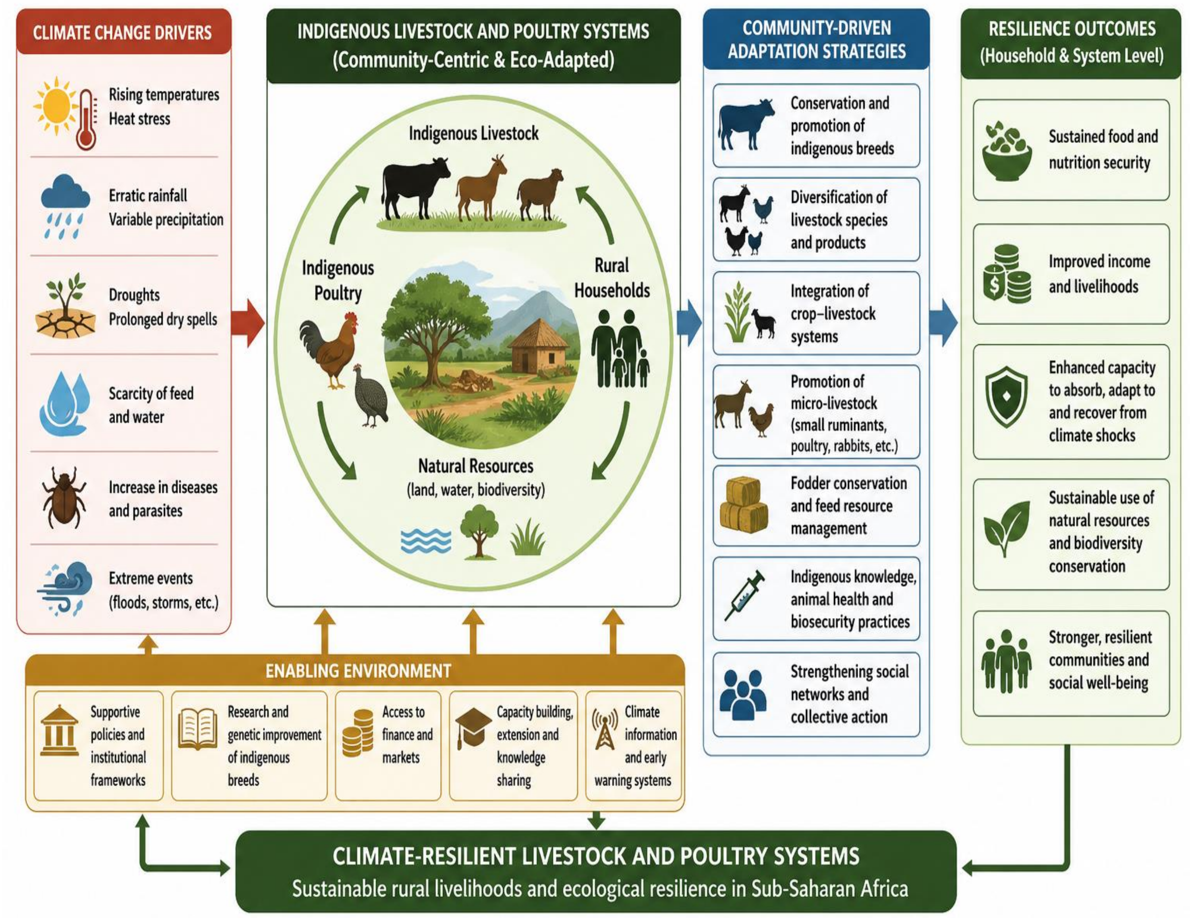

Fig 1: Conceptual Framework: Building Resilience in Indigenous Livestock and Poultry System Under Climate Change

Urgent investment in action research, climate-resilient feed systems (e.g., perennial fodder crops), and supportive policy frameworks is required. National governments must prioritize public awareness campaigns, strengthen agricultural extension services, and expand access to climate-smart innovations (Amole *et al*., 2024; Opio *et al*., 2021) [5, 63]. Promoting the development of indigenous livestock and poultry systems, especially those grounded in hardy climate-adapted breeds, is essential for sustaining rural livelihoods under intensifying environmental uncertainty. While smallholders actively implement context-specific solutions, their efforts must be reinforced by institutional mechanisms and comprehensive policy support to ensure their long-term viability and resilience.

3. Indigenous Livestock and Poultry Genetic Resources: A Pillar of Resilience for Rural Livelihoods in Sub-Saharan Africa

Sub-Saharan Africa (SSA) harbors a vast diversity of indigenous livestock and poultry genetic resources that are deeply embedded in the region's food production systems and rural livelihood. These genetic resources provide indispensable socioeconomic and ecological services to resource-constrained households (Akinola *et al*., 2021; Chingala *et al*., 2023) [67, 49]. Indigenous breeds, which are uniquely adapted to local agro-ecological conditions, play a critical role in enhancing food and nutrition security, sustaining household economies, and reflecting cultural identities. For smallholder farmers, these animals function not only as a source of sustenance but also as a form of wealth, insurance, and livelihood stability (Gwala *et al*., 2022) [28].

Across SSA, each country or regional bloc possesses distinct indigenous livestock, and poultry breeds that are well suited to the prevailing environmental conditions. Typically reared under low-input, free-range systems, these animals are favored for their adaptability, accessibility, and ability to thrive under feed and water scarcity (Mwai *et al*., 2020; Terefe *et al*., 2024) [48, 39]. Their adaptive traits, including heat tolerance, disease resistance, reproductive efficiency, and capacity to utilize low-quality local feed resources, are indispensable for the sustainability of smallholder agricultural systems (Yakubu *et al*., 2021) [76].

In the context of accelerating climate variability, building the resilience of smallholder production systems is strategically imperative. Indigenous animal genetic resources (AnGR) are key instruments for enhancing adaptive capacity to climate-related challenges such as prolonged droughts, disease outbreaks, and seasonal feed shortages (Ncube *et al*., 2025) [68]. These breeds harbor valuable genetic traits honed over generations of natural selection and environmental adaptation, positioning them as integral components of climate-smart livestock development strategies (FAO, 2021; Mapiye *et al*., 2023) [21, 16]. Evidence suggests that indigenous small ruminants and poultry exhibit greater resistance to climatic shocks than their exotic counterparts, thereby supporting more stable productivity in the face of environmental stressors (Ngigi *et al*., 2020) [56].

Despite their resilience and utility, indigenous breeds remain undervalued and underrepresented in national livestock development programs and policy frameworks across SSA. The increasing emphasis on intensive production systems using exotic breeds poses a serious threat to the conservation and continued use of indigenous livestock. These exotic breeds typically require high management inputs, substantial veterinary care, and optimal feeding regimes, rendering them ill-suited to the prevailing biophysical and infrastructural constraints in rural areas. Consequently, they often experience high mortality rates, poor reproductive performance, and increased susceptibility to disease and environmental stress (Mwai *et al*., 2022; Bett *et al*., 2020) [48, 10].

The advent of modern genomic technologies presents significant opportunities for the characterization, conservation, and strategic utilization of indigenous breeds in sustainable breeding programs. Genomic tools can facilitate the identification of valuable traits and support the development of resilient genotypes that combine adaptability with improved productivity. Prioritizing genetic characterization and mapping is essential to inform targeted conservation strategies and selective breeding initiatives that align with climate resilience goals (Nyamushamba *et al*., 2017; Marshall *et al*., 2019) [60, 40].

Beyond their biological advantages, indigenous livestock and poultry contribute profoundly to the cultural, economic, and social fabric of rural SSA. They serve as critical components of household risk management systems and offer sustainable sources of high-quality animal products under low-input organic production systems. These attributes are particularly vital in food-insecure and climate-vulnerable regions (Dossa *et al*., 2015; Yakubu, 2020) [15, 77].

However, persistent policy neglect represents a major constraint to the mainstreaming of indigenous AnGR. Many national agricultural policies continue to prioritize exotic and commercial breeds while overlooking the strategic importance of indigenous livestock systems in fostering climate resilience and rural development. This neglect has led to a gradual erosion of indigenous populations, as some smallholders have transitioned to exotics despite their limited success in low-resource environments (FAO, 2015; Rischkowsky *et al*., 2021) [20, 67].

To ensure sustainable rural livestock production and resilient food systems, national and regional policies must urgently prioritize the conservation, improvement, and promotion of indigenous animal genetic resources. Integrating indigenous breeds into national agricultural development plans can empower smallholder farmers to better manage climate risks, enhance productivity, and maintain their livelihoods under changing environmental conditions (Sarker *et al*., 2023; Nandolo *et al*., 2018) [68, 51].

Ultimately, indigenous livestock and poultry genetic resources are the cornerstones of climate-adaptive agriculture in sub-Saharan Africa. Rather than being supplanted, these breeds must be recognized, protected, and advanced alongside improved genotypes to promote a more balanced, resilient, and sustainable rural livestock sector (Leroy *et al*., 2022; FAO, 2023) [38, 22].

4. Household-Level Adaptation Strategies

4.1. Integrated Crop–Indigenous Livestock and Poultry Systems for Climate Resilience and Fodder Security

Adopting integrated crop–indigenous livestock and poultry systems at the household level is a long-established and contextually appropriate strategy for enhancing agricultural resilience against escalating climate variability. In sub-Saharan Africa, smallholder mixed farming, in which households cultivate crops alongside rearing indigenous livestock and poultry, remains a predominant practice (Mulwa & Visser, 2020; Martey *et al*., 2021) [46, 33]. Within these systems, livestock typically graze on communal or fallow rangelands, whereas poultry subsists on household food scraps and foraged resources. Mixed crop–livestock systems exhibit relatively high resilience indices, making them a viable adaptive pathway for sustaining rural livelihoods in the face of increasing climate uncertainty (Eriksen *et al*., 2024; Eriksen *et al*., 2021) [17, 30].

Rooted in indigenous knowledge and refined over generations, these systems have evolved to buffer households against environmental stress by optimizing the use of limited natural resources and generating diversified income and food. This diversification is particularly critical in rangeland-based ecosystems, where climatic unpredictability is intensifying (Moseley, 2022) [17]. As communal grazing areas continue to decline due to agricultural expansion and land-use changes, smallholder farmers are adapting by regulating herd and flock sizes in response to these resource constraints. Managing the number of animals per household has emerged as a crucial resilience strategy for both pastoral and agro-pastoral systems. This reduces the pressure on increasingly scarce feed and water resources and helps mitigate the adverse effects of recurrent droughts (Paul *et al*., 2023; Vanlauwe *et al*., 2023) [17, 34].

While traditional pastoralist strategies emphasized mobility to manage risk, the deliberate control of herd size now represents a more sustainable and locally feasible adaptation measure under current socio-ecological constraints. It allows households to better align livestock numbers with the carrying capacity of shrinking rangelands and to maintain productivity during climate-induced stress periods (Muhanguzi *et al*., 2022) [46].

4.2. Micro-Livestock and Climate-Resilient Livelihoods in Sub-Saharan Africa

Smaller livestock species, such as goats, chickens, and guinea fowl, are particularly well adapted to resource-constrained environments and exhibit greater resilience to climate-induced stressors, providing flexible and reliable sources of income and nutrition for rural households (Peacock, 2005; Assan, 2014) [64, 68].

4.2.1. Declining Landholdings and the Role of Micro-Livestock

Rapid population growth across sub-Saharan Africa has led to the progressive fragmentation of rural landholdings, with each successive generation inheriting increasingly smaller parcels of land for cultivation and livestock rearing (Jayne *et al*., 2021) [33]. In this context, the rearing of micro-livestock, such as chickens, ducks, goats, and sheep, has emerged as a strategic response to declining land availability, offering a practical pathway to enhance household food and nutrition security (Tadesse *et al*., 2022) [70]. While intensification of micro-livestock systems may be viable in select contexts, the overarching challenge of declining land productivity, driven by overuse, soil exhaustion, and degradation of grazing and browsing areas, continues to constrain their sustainability (FAO, 2023) [22].

Micro-livestock are integral to the resilience of rural livelihoods, particularly as climate change intensifies production risks. Projected increases in temperature, shifts in rainfall patterns, and depletion of natural resource bases are expected to exacerbate the vulnerability of these systems (Thornton *et al*., 2021) [72]. However, certain species, especially indigenous goats and native chickens, demonstrate robust adaptive traits, including efficient feed utilization, heat tolerance, and disease resistance, positioning them as pivotal assets in climate-resilient agriculture (Gebremedhin & Moyo, 2020; Mpenda *et al*., 2021) [28, 44].

Although both large and small livestock species contribute significantly to rural economies, larger ruminants are generally more susceptible to climate-related stressors such as droughts, heat waves, and vector-borne diseases. Consequently, identifying and promoting hardier, low-input species with proven resilience to climatic variability is essential for ensuring long-term sustainability and food system stability in the region (FAO & UNEP, 2022; Njarui *et al*., 2024) [18, 58].

4.2.2. Indigenous Chickens and Resilient Rural Agriculture

In low-income, food-deficit developing countries, rural households contribute up to 70% of the total poultry production. Globally, approximately 80% of poultry species are raised under traditional village-based systems, which account for up to 90% of the total poultry products in certain regions (Besbes, 2009). In rural sub-Saharan Africa, indigenous chickens dominate poultry production, although species such as ducks, geese, and turkeys also play vital roles in supporting household economies in the region.

Indigenous chickens are deeply embedded in rural agrarian systems, serving a broad spectrum of sociocultural, nutritional, and economic functions (Padhi, 2016; Khan, 2008; Mtambo, 2000). Their widespread presence across diverse agroecological zones reflects their adaptability and the influence of cultural preferences and heterogeneous production objectives (Ajayi 2011; Bett *et al*. 2015; Magothe *et al*. 2012; Vali 2008) [3, 15]. This variability has contributed to the remarkable genetic diversity observed in the native chicken populations of this region.

Owing to their adaptability, resilience, and low input requirements, native chickens are particularly suited to the resource constraints of smallholder systems in developing countries. Their traits include strong disease resistance, high foraging efficiency, and the ability to thrive under minimal husbandry and veterinary intervention (Padhi, 2016; Assan, 2014). In addition to supplying meat and eggs, they provide organic fertilizer, function as liquid household assets, and offer a form of informal insurance against livelihood shocks (Besbes, 2009).

Centuries of natural and human selection have refined the adaptive attributes of indigenous chickens, endowing them with tolerance to tropical heat, resilience to endemic diseases, and reproductive efficiency under extensive low management systems (Lawal *et al*., 2018; Wang *et al*., 2015) [36]. Despite their relatively low productivity compared to exotic breeds, indigenous chickens exhibit strong maternal behavior, broodiness, and excellent scavenging ability, making them ideal for free-range systems in rural areas (Tadelle, 2013; Dessie *et al*., 2011) [13].

Their capacity to withstand erratic feed and water availability, along with the use of traditional ethno-veterinary practices, underscores their value in sustaining rural livelihoods under increasing climatic pressure. Given their ecological, economic, and cultural significance, revitalizing and scaling up indigenous chicken production should be central to efforts aimed at building climate-resilient and food-secure rural agricultural systems in the Philippines in the future.

4.2.3. Indigenous Goats: Climate Adaptation and Functional Resilience

As of 2012, Africa accounted for approximately 35% of the global goat population, the majority of which comprised indigenous breeds (FAO, 2014). These goats are vital for enhancing resilience in resource-constrained, climate-vulnerable regions of sub-Saharan Africa because of their remarkable adaptability to heat stress, feed scarcity, and water shortages, which are core challenges associated with increasing climate variability.

Indigenous goats are increasingly recognized as climate-smart livestock in smallholder systems. Their small body size translates into lower maintenance requirements and facilitates dynamic herd-size adjustments in response to resource fluctuation. Physiological and behavioral adaptations enable goats to thrive in arid and semi-arid environments, where other livestock species often fail (Peacock, 2005; Campbell, 1998; Devendra, 1990) [64].

Compared with cattle and sheep, goats exhibit superior tolerance to heat and water stress (Azizi 2012). Their resilience is attributed to low basal metabolic rates, efficient thermoregulation, and flexible feeding strategies. Morphological traits, such as long limbs, narrow muzzles, and split upper lips, enhance their capacity to forage across varied and difficult terrain (McGregor, 2000). Additionally, light-colored coats and specialized hair structures mitigate heat absorption and reduce thermal stress (Adedeji, 2012; Hetem, 2010; Silanikove, 2000).

Goats also possess advanced physiological mechanisms for heat dissipation, including elevated respiratory rates and evaporative cooling via tongue extension (Hales & Brown, 1974). Their behavioral thermoregulation, resting during peak heat, and grazing during cooler hours further support survival in extreme climates (Cain *et al*., 2005).

Feeding behavior is a cornerstone of adaptability in animals. As browsers, goats consume tree leaves and shrubs that remain accessible during droughts, unlike grasses that wither under high temperatures. Their narrow muzzles facilitate efficient grazing on short pastures, and their selective feeding habits enable them to avoid toxic plants while utilizing a wide array of low-quality forages and weeds (Hofmann 1989; Provenza 1992, 1997; Lechner-Doll *et al*. 1995).

Notably, goats can metabolize forages containing high levels of anti-nutritional factors, allowing them to thrive in areas with limited feed diversity and availability. Their rapid recovery from nutritional stress and high reproductive efficiency further reinforces their suitability for climate-resilient livestock systems (Horst 1984; Aziz 2010).

Given their broad ecological distribution, physiological hardiness, and versatile feeding strategies, indigenous goats are a critical asset for rural communities facing the twin pressures of climate change and natural resource degradation. Promoting and integrating these goats into smallholder farming systems could substantially bolster food and livelihood security in sub-Saharan Africa.

5. Diversification of Indigenous Livestock and Poultry for Climate Resilience in Smallholder Systems

Maintaining multiple livestock species with distinct adaptive traits provides a natural buffer against environmental variability, thereby reinforcing household resilience (Ngigi, Mueller, & Birner, 2020) [56]. On-farm agro-biodiversity among smallholders enables risk distribution across spatial and temporal dimensions, embedding long-term adaptive capacity within rural agricultural systems (Dossa *et al*., 2021; Kassie *et al*., 2022) [16, 34]. Within this framework, diversifying indigenous livestock and poultry portfolios has emerged as a pragmatic strategy to enhance resilience to climate risks while advancing the well-being of smallholder farming households.

A central approach involves integrating species and breeds that are genetically or behaviorally suited to hotter and increasingly unpredictable climates. Multispecies rearing, which is now widely adopted in rural communities, broadens the range of coping mechanisms available to the households. Ngigi *et al*. (2020) [56] highlighted that small ruminants and poultry are generally more resilient to climatic shocks than large ruminants, rendering them particularly valuable to resource-poor households. In such settings, livestock diversification, combined with informal safety nets such as rotating savings groups, helps households maintain food consumption and absorb environmental and economic shock. The extent of diversification often reflects disparities in household size, labor availability, and access to financial capital. Nevertheless, investing in indigenous livestock and poultry diversification represents a viable strategy for poverty reduction, given its role in enhancing the resilience and sustainability of smallholder production systems (Mwango *et al*., 2023) [49].

With limited non-agricultural employment opportunities and continued rural population growth in sub-Saharan Africa, integrated crop and livestock farming will remain a cornerstone of food and nutritional security in the region. While much of the policy and academic discourse centers on boosting crop yields, improving the productivity and climate resilience of indigenous livestock and poultry systems is equally vital, especially considering the intensifying climate threats to both crop and animal agriculture (Opio *et al*., 2021; Amole *et al*., 2024) [63, 5].

Diversification continues to serve as a foundational risk management and adaptation strategy in rural, agricultural settings. While general agricultural diversification may have marginal impacts, the diversification of livestock and poultry species specifically targets climate-related vulnerabilities. Given their differing sensitivities to temperature, disease, and water scarcity, maintaining a mixed-species herd —such as cattle, goats, and sheep—allows households to mitigate risks more effectively. Moreover, households that integrate both crops and livestock tend to achieve superior food security (Mutambara *et al*. 2022) [46].

Among the poorest households, indigenous species are typically selected to meet a broad range of subsistence and livelihood objectives. Within ruminant systems, the increasing incidence of drought, bush encroachment, and heightened susceptibility of cattle have led many farmers to transition toward hardier species such as goats. This adaptive behavior aligns with ecological theories that emphasize functional diversity as the cornerstone of resilience in agricultural systems (Gwitira *et al*. 2021) [30].

The diversification of livestock and poultry species also contributes to ecological function, as each species occupies a distinct ecological niche. For example, cattle (grazers), goats (browsers), and sheep (intermediate feeders) exhibit complementary foraging behaviors that optimize resource use across variable landscapes. Such species complementarities not only improve forage efficiency under constrained conditions but also reinforce the long-term sustainability and adaptability of smallholder agricultural systems (Dube *et al*., 2023) [17].

6. Animal Nutrition as a Climate-Smart Intervention

Prioritizing diet quality and the utilization of drought-tolerant feed resources, such as crop residues and biofortified forages, supports livestock health while reducing greenhouse gas emissions, exemplifying climate-smart nutritional strategies in semi-arid environments (Maluleke & Mokwena, 2025) [39]. However, seasonal fluctuations in Rangeland productivity and fodder availability, exacerbated by erratic rainfall patterns, pose widespread challenges in rural sub-Saharan Africa. These feed constraints significantly undermine the productivity and sustainability of indigenous livestock and poultry rearing.

Climate change has intensified feed scarcity, and the increasing rural populations and subdivision of communal lands for crop production have further diminished the grazing resources. As arable land expands at the expense of rangelands, many smallholder farmers are shifting from large livestock to smaller, more adaptable species, including goats, sheep, indigenous chickens, ducks, and guinea fowls.

To mitigate feed shortages, research institutions have developed improved forage varieties tailored for dry agroecological zones (Maina *et al*., 2020). Where land remains available, expanding fodder cultivation offers a viable pathway to enhance the productivity of indigenous livestock and poultry, thus contributing to household income and alleviating poverty.

Indigenous breeds, such as native goats and chickens, possess genetic traits, such as heat tolerance, disease resistance, and efficient feed utilization, which support climate-resilient production (Ajayi *et al*., 2011; Dessie *et al*., 2011) [3, 13]. The conservation of these traits strengthens livestock system resilience and underpins ongoing genomic research aimed at enhancing adaptation across rural contexts (Wang *et al*., 2018; Lawal *et al*., 2018) [73, 36].

Empowering livestock-dependent communities requires integrated policy support for extension services, breed conservation, and greenhouse gas emissions mitigation. Regional partnerships and training initiatives should continue to embed climate-smart livestock practices into national development and climate adaptation plans (Food for Mzansi, 2023; CCARDESA, 2024) [24, 11].

A multidimensional strategy is needed to strengthen the conservation and adaptive capacity of indigenous genetic resources in Sub-Saharan Africa. This strategy should align with scientific research, community-based practices and policy frameworks (FAO, 2015; Mwacharo *et al*., 2017) [20, 47]. Given their critical role in food security, rural livelihoods, and climate resilience, indigenous livestock and poultry conservation must be prioritized through in situ and ex situ approaches (Rege & Gibson, 2003; ILRI, 2021) [66, 32].

In situ conservation focuses on maintaining genetic diversity under natural conditions, emphasizing the role of community-based breeding programs, indigenous knowledge, and diversified agro-pastoral systems (FAO, 2007; Gizaw *et al*., 2013) [19, 29]. In contrast, ex situ approaches involve the cryopreservation of genetic material and the establishment of gene banks and biorepositories in research institutions (Wollny, 2003; Hanotte *et al*., 2010) [74, 31]. Comprehensive documentation of phenotypic and genotypic traits is essential for facilitating future breeding innovations and adaptive responses (FAO, 2015; Mbole-Kariuki *et al*. 2014) [20, 41].

Scientific research is critical for identifying adaptive traits, such as drought tolerance and disease resistance, and integrating indigenous breeds into formal genetic improvement programs to enhance their market value and broader utility (Lawal *et al*., 2020; Yakubu, 2013) [37, 76]. Equally, empowering local communities, especially women and youth, through targeted training and extension services is essential for sustainable management and intergenerational knowledge transfer (Njeru *et al*., 2016; ILRI 2021) [59, 32]. Strengthening farmer cooperatives and expanding participatory breeding programs are vital for building resilience at the grassroots level (Mueller *et al*., 2015) [45].

Supportive national policies are needed to safeguard indigenous breeds as genetic and cultural assets, ensure fair access and benefit sharing, and guard against genetic erosion and biopiracy (Nagoya Protocol, 2011; AU-IBAR, 2015) [50, 7]. Strengthening value chains and developing niche markets for indigenous animal products, positioned as climate-resilient or ethically produced products, can increase their economic viability and consumer appeal (Kibiego *et al*., 2016; Bett *et al*., 2020) [35, 10].

Finally, mainstreaming indigenous livestock genetic resources into national climate change adaptation strategies and climate-smart agriculture frameworks is critical for building resilient and inclusive food systems (World Bank, 2017; FAO, 2021) [75, 21]. Sustained monitoring, evaluation, and innovation, including the use of digital registries, phenomics, and GIS mapping, are essential tools for tracking genetic diversity and informing adaptive livestock management (Ojango *et al*., 2016; Thornton *et al*., 2015) [62, 71].

7. Conclusion

Rural communities across sub-Saharan Africa depend extensively on indigenous livestock and poultry, which are uniquely adapted to local agroecological conditions and climate-related stressors. Increasing climate variability, characterized by erratic rainfall, prolonged droughts, and rising temperatures, has exacerbated disease prevalence, feed and water scarcity, and an overall decline in livestock productivity. In response, smallholder farmers are proactively enhancing their resilience through a range of adaptive strategies, including conservation of local breeds, crop–livestock integration, micro-livestock rearing, fodder preservation, and species diversification.

Establishing climate-smart livestock systems by integrating improved nutrition, adaptive genetics, animal health services, and an enabling policy framework is critical for safeguarding socioeconomic well-being, nutritional outcomes, and environmental sustainability in vulnerable regions. This review synthesizes key climate risks, farmer-led adaptation practices, and emerging policy interventions, focusing on the central role of indigenous animal genetic resources in building the resilience of smallholders.

The convergence of genetic adaptability, household coping mechanisms, and institutional support underpins climate resilience and enhances rural livelihoods in Sub-Saharan Africa. Prioritizing climate-smart livestock systems anchored in diversified species, resilient feed strategies, genetic improvement, and robust extension services will be instrumental in advancing food security and sustainable development across the region in the future.

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