

Perspective

Climate Change's Impact on Agriculture and Food Security: An Opportunity to Showcase African Animal Genetic Resources

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Abstract: One of the current issues facing humanity is ensuring sustained global food security in the face of devastating effects of climate change; this challenge is particularly pressing on the African continent. Here, I present an opinion piece identifying local animal genetic resources as "African leverage point" that provide the highest chances to cushion rural folk to climate change, enhance environmental sustainability and food security in Africa. When it comes to boosting food production, coping with climate change, or bolstering the delivery of a wide range of ecosystem services, I believe that African animal genetic resources are essential alternatives for the sustainable growth of the livestock industry and its contribution to food security. Africa needs to address the support and development of indigenous animal genetic resources in order to meet the basic food needs of more than 1 billion people, address numerous environmental issues with continental implications, and focus on more effective and resilient food systems with the greatest impact on food security. The indigenous animal resources diversity and support actions to this unique group could provide a boost in protein that is lacking to constitute healthy diets in Africa. The priorities of nonprofit organizations, foundations, governments, citizens' groups, and companies can be influenced by this leverage point in the African food system. Due to continuous food insecurity, which appears to be becoming worse with climate change and makes it even harder to accomplish the SDGs on the continent, Africa has paid a hefty price for being misled about the worth of its own animal genetic resources. To the contrary, it is highly improbable that a strategy to improve food security and rural livelihoods that undermines the utilization of indigenous animal genetic resources will be viable in long-term. If Africa makes an effort, is committed, and fully commits resources to putting indigenous animal genetic resources at the forefront of combating food insecurity and accelerating the achievement of SDGs, it can achieve more under the adverse prevailing climate change induce environmental conditions. Our personal opinion is that we would not have had the ongoing food problems, even in the face of climate change, if Africa had over the years implemented the necessary mechanisms to develop and promote local animal genetic resources. What lies ahead in terms of climate change effect on food security in Africa is anyone's guess – but whatever it is, promoting continental adapted indigenous animal genetic resources portfolio is ready to handle it. Development and promotion of African animal genetic resources should be part of a continental strategy to transform smallholder animal production by 2050, in line with the goals of achieving the SGDs, to improve rural household food security, and bringing rural economy prosperity, resilience, sustainability, and all other desired animal related food outcomes for rural healthy diets. African animal genetic resources are the most important but underutilized resource to address the issue of ongoing food insecurity. The responsible use of local animal genetic resources through climate smart animal husbandry practices also contributes to food security, rural development and increased employment opportunities. African genetic improvement programs involving indigenous animal genetic resources must be considered as regards to local agriculture and livestock development aspirations, appropriateness to local reality and livelihood security, as well as environmental friendliness. Animal agriculture will fill in the enormous gaps in the continent's food supply if this animal group receives adequate attention and is used integrated properly in crop and livestock systems which characterize smallholder farming sector in

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Africa. Because they have evolved over time to accommodate the various climatic conditions and environmental pressures on the continent, Africa's native animal genetic resources are particularly resilient. Indirectly, the impact of climate change offers a chance to use native animal genetics from Africa. The use of local animal genetic diversity has the potential to substantially improve Africa's food security landscape hence should be given special consideration for sociocultural, environmental, and economic aspects, and with regard for smallholder farmer-specific factors of interest. African animal genetic resources have contributed significantly to the food and nutrition security aspects of the millions of people in their communities of origin and custody in Africa. The purpose of the perception piece is to educate the reader about the fundamental mechanisms that control the use of continental animal genetic resources and how the outlook for these mechanisms can be manipulated in the future for the benefit of improving food security in Africa. The discussion provides in-depth insight into the pertinent literature in understanding the significance of local animal genetic resources in terms of their contribution to food security in Africa.

Keywords: Climate Change, Local Animal Genetic Resources, Food Security, Gender Inequality, Small Scale Agriculture, Africa

1. Introduction

African animal agriculture, which is dominated by indigenous (local) animal genetic resources, is an important livelihood strategy for poor farmers in Sub-Saharan Africa's pastoral, agro-pastoral, and mixed crop-livestock systems [1]. Animal genetic resources are here taken to encompass those animal species that are utilized, or may be used, for food production and agriculture, as well as the populations within each,' according to the report from [2]. Sub-Saharan Africa has extensive local animal genetic resources that have long been an important source of food and nutrition security, with the role of imported animal genetic resources being recognized as a complementary. Because of the extensive genetic diversity in livestock and avian domesticated species, animal agriculture can exist in all but the most extreme environments in Africa, providing a variety of products and functions. However, in this context climate change has been identified as a major limiting factor in the productivity of animal agriculture in Africa.

Globally, the primary source of food has shifted in the last 50 years from grains to animal protein, resulting in significantly increased livestock production [3], which may have implications for food security, particularly in Africa, which has a diverse range of animal genetic resources. The transformation of small-scale animal agriculture through promotion of the diverse range of indigenous animal genetic resources could substantially improve the food security landscape on the continent. This on the backdrop that the world's population continues to grow, while Africa is leading on this aspect hence agriculture faces the challenge of producing enough food to meet rising demand due to changing climate and natural resource depletion [4].

Climate change may have an impact on food security in Africa because it will be harder to raise animals hence the need for adapted animals such as local animal genetic resources. Unfavorable weather conditions are frequently getting worse, which makes animal productivity even more erratic. Extreme weather events are anticipated to happen more frequently and/or more severely as temperatures rise and rainfall patterns change even more than they already have. In the context of the current climate adversity as an opportunity rather than a catastrophe, this opinion piece aims to shed light on the role of regional animal genetic resources for food security. Because it provides calories, proteins, and essential micronutrients on a global scale and is practiced in areas where crops are challenging to grow, animal agriculture significantly enhances food security.

Modern molecular breeding techniques can be utilized to boost local animal genetic resources performance contribution food production while maintaining food security and resilience. It is possible to develop and implement a local animal genetic resources utilization model for Africa, aided by modern molecular genetic technologies, to assist the continent in addressing the issue of feeding a rapidly rising population and food insecurity. At the moment, the best way for the livestock sector to contribute to food security is to emphasize the importance of food balance [5] through reducing productivity and consumption gap. This paper argues that, if given sufficient consideration, the use of local animal genetic diversity has the potential to substantially improve Africa's food security landscape. The discussion takes into account the importance of local animal genetic resources, as well as potential paradigm shifts that could be implemented to increase the sector's value and improve food security across the continent.

2. African animal genetic resources' numerical dominance, climate change and food security

The numerical superiority of African animal genetic resources may be harnessed to address rural poverty and food security under current climate change adverse conditions. For Africa the enhancement of food security is intertwined with the endowment of local avian and animal genetic resources, both directly and indirectly. If this connection is appreciated and taken into account, it will be able to address Africa's persistent food insecurity. Africa's wide array of animal genetic resources, albeit underutilized in the past, have the potential to significantly enhance food security and the continent's economic growth [5]. More than 800 million impoverished livestock keepers manage about one billion animals in peri urban, rural, and marginal settings in developing nations [6]. Cattle, sheep, goats, donkeys, camels, and poultry are the most prevalent animals in Africa. They include both direct and indirect impacts on the entire food supply as well as the security of food and nutrition [7]. Livestock will have a bigger role in Sub-Saharan Africa in the future because the demand for animal-source food is anticipated to increase as a result of population growth, rising incomes, and urbanization.

Livestock accounts for between 30% and 80% of the agricultural GDP of African countries. Sub-Saharan Africa is home to 20–25 percent of the world's ruminants, and there is a tremendous amount of livestock there, especially ruminants. Studies show that 150 million rural poor people in Sub-Saharan Africa, or nearly 70% of the population, depend on cattle for at least some of their income, with pastoralists making up the majority of this group [8]. Africa is home to one-third of the world's cattle, and its agricultural industry accounts for nearly 40% of the continent's total GDP, according to [9]. Africa raises 1.5 billion chickens, with local chicken groups accounting for 80% of them [10] contend that native chickens make a major contribution to the food security and economic viability of rural households. According to [11] and [12], one of the reasons why chicken farming would be considered as a quick solution to try to reduce rural poverty is because it is a sort of farming that most rural people are familiar with.

Goats and sheep, were estimated at 490 million and 420 million heads, respectively. Around a billion goats are thought to exist worldwide, with Asia and Africa housing the majority of them and 35% of the goats in the world are found in Africa [13]. 30% of domestic ruminants currently found on the African continent are goats [14]. Goats are essential for enhancing livelihoods and ensuring food security in Africa. Most indigenous and locally adapted goats are kept in small-scale agricultural systems in rural areas of Africa. Africa produced 1.3 million tons of goat meat in 2017 compared to 1.1 million tons in 2008 [15].

The statistical dominance of native genetic animal and avian species on the continent suggests that effective animal production strategies that focus on the small-scale farmers who are the animals' custodians will go a long way toward enhancing animal production

output and thereby enhancing food security. These animals are the only source of a healthy diet for the majority of rural Africa.

3. Food security, indigenous animal genetic resources use, and climate change consequences and adaptations

The effect of climate change will exacerbate food security risks and threaten to undermine progress against malnutrition and hunger in the most vulnerable countries, particularly in resource-poor rural communities [16]. The most vulnerable breeds may be seriously threatened by climate change, which is anticipated to put livestock systems to the test and necessitate stepping up conservation efforts. Due to its reliance on rainfall, small-scale animal agriculture is seriously threatened by climate change. Any program that boosts productivity in small-scale animal agriculture dominated by local genetic resources should include any measures that will mitigate the negative effects of climate change on this sector. Climate change is a current global concern, and despite ongoing debate about the extent and significance of its causes and effects, it appears likely that it will have an impact on agriculture and food security, particularly in rural poor communities of Africa. Droughts are one of the most important factors that amplify the effects of climate change because they have a negative impact on pastoral livestock production.

Changes in mean climate and increasing climate variability are affecting natural rangelands carrying capacity, threatening livelihoods for the majority of people who rely on animal agriculture for food security and the health of grassland ecosystems [17]. Environmental factors have an impact on the potential production of animals used for agriculture, so farmers should be aware of management risks and mitigation techniques to increase animal production in the face of climate change challenges. Smallholder farmers have come up with a number of climate smart animal production techniques to help them adapt to the various risks posed by climate change. Improving smallholder farmers' adaptive capacity is a practical way to deal with climate change while also improving agriculture production and thus ensuring food security. Small-scale farmers' adaptive capacity could be increased by enabling them to cope better with feed and water scarcity, as well as animal health issues, through appropriate policy measures and institutional support. Environmental stressors caused by climate change have been linked to livestock capacity decline on grazing land due to their impact on severe feed shortages caused by changes in rainfall patterns and water scarcity.

Climate change is expected to have a significant impact on forage crop quality and quantity. Extreme temperature events, such as droughts and heat waves will also threaten food availability for livestock. Warmer temperatures caused by climate change may degrade pasture quality and quantity, making it more difficult for small-scale farmers to match production to the nutritional needs of their animals. Animal populations will be exposed to energy, protein, phosphate, and calcium deficiencies as a result of feed scarcity or insufficient grazing due to climate change, resulting in low conception rates, retained afterbirths, poor quality colostrum, and immune deficiencies. Drought intensity and duration, as well as long-term climate trends, had a significant impact on forage production and animal stocking rates. Livestock is the main consumer of forage and pasture. The animal productivity will be impacted by any negative climate change consequences on the plant genetic resources utilized as feed resources mainly on rangelands, such as reduced availability, altered nutritional value, and increased costs. Climate-related factors will also affect forage and pasture growth, which is expected to affect grazing animals' performance and shift the agro ecological regions to which particular animal genetic resources are adapted.

As future climate changes make managing rainfall variability more difficult, active adaptive management and research will be required [18]. A significant amount of research is being conducted to better understand the interaction of climate change and agricultural

production [19]. However, there has been little research into the effects of climate change on livestock production [20]. Animal production that is entirely dependent on rangeland will have to become more adaptable in the face of future climate trends. Adoption of climate smart animal agriculture methodologies may be beneficial; however, where and when they can be implemented, as well as the enabling mechanisms needed to implement them, will be critical for effectively improving rangelands and pastoralists' livelihoods through improved animal production to increase food security.

Animal health and production are impacted by climate change both directly and indirectly [21]. However, uncertainty exists over the extent to which climate change will heighten the harm that epidemics offer to the diversity of animal genetic resources. However, it is likely that the climate will have an impact on the distribution of diseases carried by vectors like insects and ticks [22]. Emerging diseases may find favorable ecological niches as a result of climate-driven changes to landscape structure and texture, as well as other variables and more general considerations. Abiotic conditions have an impact on the bionomics of pathogens, reservoirs, and vectors, as well as their capacity to colonize new habitats. Disease behavior in terms of pattern of spread, diffusion range, amplification, and persistence in unfamiliar environments may be impacted by changes in climatic patterns and seasonal conditions. Because of the complexity of interactions between diseases, vectors, host animals, and other components within an ecosystem, as well as the influence of a wide range of external factors and management methods, outcomes in terms of disease epidemiology are challenging to predict. The anticipated rise in livestock disease outbreaks, some of which are novel, will favor genotypes that are tolerant or resistant to the aforementioned disease [23].

The distribution and abundance of disease vectors may be impacted by changes in temperature and rainfall patterns, as well as by the frequency of extreme weather events [24]. The proliferation and spread of parasites, as well as the reproduction, virulence, and transmission of infectious pathogens and/or their vectors, are a few examples of indirect health effects. Heat stress, metabolic disorder, oxidative stress, and immune suppression have a significant impact on livestock health as a result of more frequent extreme weather events, such as higher temperatures. This increases the risk of disease development and mortality. Because they spend a significant portion of their life cycle in a cold-blooded host invertebrate whose temperature is similar to the environment, pathogens spread by vectors are especially sensitive to climate change [25]. Optimizing preventive measures will eventually result from knowing how climatological and ecological change relate to disease emergence and redistribution [26]. It is necessary to describe animal health adaptation and mitigation measures that can be used specifically in the livestock industry to lessen the effects of livestock diseases linked to climate change.

As temperatures rise due to climate change, water availability and quality (for drinking, forage, and feed crops) will become critical if we are to sustain animal production in the smallholder farming sector and improve food security. Due to their impact on water resources, climate change and variability have been identified as the main causes of low livestock productivity [27]. A comprehensive livestock and water planning, development, and management strategy has the potential to reduce poverty, increase food production and security, and alleviate environmental pressures such as the use of scarce water resources. Given the predicted future water scarcity, strategies for improving water-use efficiency and conservation for diverse animal production systems in various agro-ecological regions must be developed. However, it is the duty of farmers to ensure that their animals have access to enough and clean water in order to set the stage for improved performance, which results in increased production and food security.

Animal water consumption is predicted to increase by a factor of three, agricultural land demand will rise due to the need for a 70% increase in production, and food security concerns will limit livestock production. Community-based research is needed to understand the vulnerability of water resources to climate change and to support the

development of adaptive animal production strategies for Africa's vulnerable smallholder farmers, who are the backbone of food production. Addressing climate-water-induced challenges requires first a better understanding of what water inventory is available in agro-ecological regions and how it matches current and future animal production needs. Increasing water scarcity as a result of climate change, increased animal production needs, and competing demands especially on crop use necessitate optimizing water resource use to maximize animal performance and secure food security.

Animals are impacted by heat stress in a variety of ways. Their need for water increases, they consume less food and engage in less physical activity, and they use more metabolic energy to maintain their body temperature. Stress caused by a shortage of drinking water reduces animal production [1]. Many factors influence the amount of water livestock drink, including species, breed, ambient temperature, water quality, feed levels and water content, animal activity, pregnancy, and lactation [28]. All of the negative impacts of heat stress result in decreased fertility and output as well as increased mortality. Particularly in the tropics and subtropics, rising temperatures will pose serious challenges to the raising of livestock.

Environmental stress in animal production extends beyond climatic factors and includes nutrition, housing, and any stimuli that require the animal to respond in order to adapt to new circumstances [29]. Farmers' failure to identify or recognize climate change-related stress factors, as well as animal husbandry management practices that stress farm animals, may result in lower animal performance and reproductive ability, resulting in a shortage of animal and animal product supply and, as a result, food insecurity. However, it is the responsibility of farmers to guarantee that their livestock has access to sufficient and hygienic water in order to create the conditions for improved performance, which leads to increased output and food security. Three times as much water will be consumed by animals, which will increase the demand for agricultural land.

4. African specific animal genetic resources for adaptability and food security

Numerous authors have emphasized that goats [30, 31] and chickens [32, 33] besides serving as an entry point for gender equality it is crucial for the production of animal-related sustenance and food security. Indigenous goats and rural poultry, especially indigenous chickens have proved to be species that can thrive, produce, and help ensure food security in climate change-stressed environments because they are mainly found in tropical regions. The majority of smallholder rural households own either indigenous chickens, indigenous goats, or both due to their numerical dominance in most agro ecological regions across Africa. They may be managed on small land because of their small body size.

4.1. The indigenous goat is a perfect local animal genetic resource coined climate animal model for food security

The native goat is the ideal regional animal genetic resource and climatically appropriate animal model for food security. Goats are highly prized by farmers and consumers due to their adaptability and versatility, which significantly boosts household income and food security [34]. Goats are highly prized by farmers and consumers due to their adaptability and versatility, which significantly boosts household income and food security [30]. In the arid and semi-arid tropical climates that are the norm in Africa, goats are remarkably adaptable and have high production potential [35]. Around 95.7 percent of goats and 63.3 percent of ewes, which account for more than 70% of global animal production, are found in developing countries, according to [36]. Globally, there were 875.5 million goats and one billion sheep in 2011, according to the Food and Agriculture Organization [37], 80% of small ruminants are kept in developing countries in this case, with Africa being the home to many of them. By ensuring household nutritional and food security and serving as a source of family income through meat, wool/fiber, skin, milk,

and manure with minimal input, they play a crucial part in the livelihood security of marginal and landless farmers, particularly in the harsh agro-ecological conditions.

The growing number of goats in Sub-Saharan Africa indicates that their relative importance has not waned over time, and that they continue to make an important contribution to the global population, and thus food production and security. [38] provide some insight into the goat's unique characteristics as an efficient meat producer in the harsh environments that characterize the majority of semi-arid tropical conditions in Africa. Indigenous goats are valuable to rural farmers with limited resources because they help to increase food security and reduce poverty [39]. Given that they make up more than 95% of Africa's small ruminant populations and are owned by rural households in excess of 90% of the time and this numerical advantage that can be leveraged to improve food security on the continent [40]. In addition, Africa is home to 33.1% of the world's goat population [41], with poor farmers raising a greater proportion of livestock [42].

Goats are without a doubt the most prevalent and local animal genetic resource that is best suited for surviving in the tropics, despite the current worsening environmental issues caused by climate change. In this context, the crucial question is how can we increase smallholder goat and sheep production while utilizing their numerical advantage and their capacity to adapt to the harsh semi-arid continental conditions. The idea that small-scale goat farming has the potential to support livelihoods, especially in semi-arid regions where rainfall is unpredictable and crop farming is too risky, is based on the fact that goats are an animal that can survive anywhere with minimal inputs, making them an ideal animal for resource-poor farmers as a tool for poverty alleviation and food security. Goats are thought to be a species that can thrive, produce, and help ensure food security in climate change-stressed environments because they are mainly found in tropical regions.

Long drought periods have been made worse by climate change in seasonal biotopes of arid and semi-arid regions of the world, and unpredictability in the weather has hindered the production of large ruminants like cattle and buffalos, in contrast to the steadily rising goat husbandry. In these conditions, small-scale farmers view goats as a tougher animal, able to handle a variety of stressors like heat, water scarcity, and feed shortages, as well as having greater bush skills than sheep and cattle [43]. Secondly, goats have a clear advantage over sheep and cattle in dealing with seasonal biotopes with a dearth of both feed and water due to their unique ability to use behavioral plasticity and morphological traits [44].

4.2. Indigenous chicken production: climate smart animal and a key to food security

Smallholder farmers generally rear native domestic chickens using a conventional scavenging strategy in many underdeveloped nations [45, 46]. Native chickens are well-liked in these regions due to their resistance to common poultry diseases and variations in feed quality and availability, which results in minimal or no input expenditures [47]. Indigenous (village/native) chickens are an important local animal genetic resource in Africa because it can significantly lessen poverty, ensure food security, and advance gender equality. According to [48], over 80% of the world's poultry are kept in rural areas, and they significantly increase annual production of eggs and meat, particularly in Africa's low-income food-deficit countries. When compared to 2012, the estimated ten (10) billion people's need for food is expected to increase by 50% in 2050 [49].

The value of small-scale, scavenging chicken production to the national economies of developing countries in Africa, as well as its contribution to improving food security, many smallholder farmers' nutritional status, and income, has been acknowledged by numerous academics and policymakers from around the world [50]. Numerous studies have shown that indigenous chickens have a significant impact on the socioeconomic status and food security goals for the majority of rural Africa [51]. In this case in order to combat food insecurity, village chicken production must be developed. Adopting a food

production system that supports sustainable, affordable, and available to meet their nutritional needs is one way to combat the challenge of hunger and food insecurity among vulnerable in rural Africa. [52] estimates that 85% of rural households in Sub-Saharan Africa keep indigenous chickens or other types of rural poultry. This represents a sizable portion of these populations, but what is the social and economic and food security value of smallholder chicken production? Is Africa maximizing rural poultry's contribution to food security? In many developing nations, where poultry is a major component of animal protein of rural, peri-urban, and urban households, scavenging chickens still make up a sizable portion of all meat produced.

In-depth analyses of the various African animal genetic resources have also been done regarding the potential contributions and effects of small-scale scavenging poultry production systems, particularly indigenous chickens in rural, resource-poor areas, to various dimensions of food security in terms of availability, accessibility, utilization, and stability [53, 54]. Indigenous chickens (*Gallus domesticus*) can survive in a variety of challenging environments, such as extensive small-scale villages, free-range, and organic production systems and play a significant role in rural development and food security. Because they are not significantly impacted by anthropogenic effects and have a robust immune system that allows them to withstand disease, harsh conditions, global warming, and climate change, native chickens have a high genetic and phenotypic diversity.

Natural selection has primarily shaped the genetic structure of indigenous chickens, allowing them to accumulate high levels of genetic polymorphism and to adaptively radiate. Native chickens can significantly improve the food security of rural African households if these problems are resolved. Despite their significance and capacity to adapt to challenging production environments, indigenous breeds of chicken, which make up the majority of rural poultry, are less productive than temperate breeds. African small-scale farmers frequently raise native domestic chickens using the classic scavenging system [45, 46]. Due to their resistance to common poultry diseases and fluctuations in feed quality and quantity, which require little to no input, they are a dominant site in rural areas with limited resources [47].

Indigenous chickens produce a genetically diverse gene pool, which is an important resource for Africa if properly supported for growth. This approach can significantly improve nutrition and food security by offsetting the protein supply deficit, which is generally high in rural areas. Appropriate strategies to spruce up and improve chicken's contribution to nutrition and food security are unquestionably required today. Indigenous chickens are thought to contribute significantly to rural households' food security and rural economic sustainability. [55] claims that the genetic resource base of indigenous chickens in the tropics is abundant and should serve as the foundation for genetic improvement and diversification in order to generate a tropics-adapted breed, and probably this strategy will enhance rural communities' nutritional and food security in Africa.

Until recently, most African indigenous chicken populations had not been definitively classified into standard breeds and various researchers worked on characterization based on morphological, molecular, and performance traits to highlight the phenotypic variability and genetic diversity of indigenous chicken genetic resources [56]. They discovered significant genetic diversity in indigenous chickens in Africa, which represents an important genetic resource that can be conserved or optimized through genetic improvement. Indigenous chickens' genetic improvements require a clear breeding goal, long-term breeding strategies, and a thorough understanding of the genetic diversity of the dominant genotypes and ecotypes [57].

The primary goal of rural poultry development initiatives, according to several authors, has been to increase the low productivity of native chickens in developing countries [58,59,60, 61]. Elsewhere, rural poultry breeders have reported a number of genetic improvement programs with varying degrees of success [62, 63]. The future

success of rural poultry development initiatives will determine the total reliance of rural farmers on our native chicken breeds, which ultimately results in their commercialization. Understanding the genetic traits of the common indigenous chickens will therefore facilitate genetic improvement and hasten their preservation [64]. A promising approach to addressing food security in the context of the devastating effects of climate change on the continent must be taken to conserve or preserve what is left of Africa's rural poultry ecotypes.

African women make up around 70% of agricultural workers in sub-Saharan Africa and 80% of those who process food [65]. Hence gender equality, equity, and women's empowerment should be the primary drivers of African livestock and poultry development programs if Africa is to achieve the millennium development goals. Considering gender issues in poultry programs will directly involve women in rural development issues as gender plays a significant role in poultry production in much of rural Africa [66]. Chickens are frequently the only livestock that women have independent authority over in many poor nations [66]. In contrast to male-headed households, which may have various sources of income, female-headed households frequently rely primarily on the sale of poultry products [67, 68]. Contrary to men, who only channel 30–40% of their wealth back into their households or communities, women have control over 90% of it [69].

Due to its effects on African gender equality, food security, and poverty alleviation agendas, rural poultry has a multifaceted role to play. Gender considerations must be made if rural poultry, a vital local genetic resource, is to improve the continent's food security situation. In order to ensure that women's needs, abilities, and constraints are taken into account in the development of technologies, practices, and smallholder agriculture on the continent, much ground could be covered through the production of village chickens. In order to operate as an inclusive strategy based on a deep awareness of gender dynamics, indigenous chicken production must be able to meet the needs and aspirations of both men and women, as well as address problems and opportunities. Women frequently make more management and investment decisions about chickens than about other animals, however this may vary by region [70], and more women care for chickens (84 percent) than actually make decisions about their production (66 percent).

There is great deal of useful knowledge both indigenous and modern science, and practices related to indigenous chicken production accumulated over the years, which together with recognized local and cost-effective interventions incorporating improvements in the production such as nutrition (from domestic and environmental waste), housing and/or management, and/or genetics that have the prospect to achieve sustainable production of indigenous chickens for the benefit of vulnerable and food insecure rural populace. The advances made in the characterization of indigenous chickens based on morphological and phenotypic traits, which are the result of phenotypic genes that have been shown to contribute significantly to their adaptability and reproductive fitness in tropical climates [55], will not only go a long way toward genetic enhancement, but will also expedite their conservation.

Major genes such as naked neck (Na), frizzle (F), delayed feathering (K), and dwarf (Dw) could be introduced as a significant way to increase productivity in hot-climate birds [71]. Genetic improvement through within-breed selection could be a promising alternative strategy. Identification of different varieties has been made in various countries to some native chickens with genes such as naked neck (Na), frizzle (F) and crest (Cr) being prominent rural populations. Furthermore, it is thought that major marker genes confer not only adaptability to tropical climates, but also disease resistance. Many studies over the last two decades have found that the naked neck and frizzle genes improve immune-competence in high-temperature-raised chickens [72, 73]. Hence the introduction of major genes into community-based breeding programs will be critical for

future breeding strategies to improve indigenous chicken productivity and survival rates and hence food security.

Native chickens continue to predominate in many African villages, despite years of efforts to import more productive, exotic, and crossbred species of fowl. This is because more genetically efficient breeds come with significant input costs (housing/shelter, commercial feeds, and stringent disease control/vaccination programs), which local farmers have not been able to afford [74]. The production of meat and eggs from locally raised chickens, however, is one of the most environmentally friendly methods now in use for producing animal proteins [50], and chickens are by far the most significant poultry species globally [5]. Despite having subpar meat and egg output, they are an essential component of a well-balanced farming system [76].

5. Integrated crop-livestock systems are the ideal climate smart food system model for food security

Climate change's impact on local animal genetic resources can be mitigated through crop-livestock integration to improve food security. Integrated crop-livestock systems are frequently regarded as a promising approach to addressing agricultural sustainability issues, particularly in the context of adversities of climate change and variability. In a study comparing specialized and intensive systems, [77] discovered that integrated crop-livestock systems can be productive, sustainable, and climate-resilient agricultural systems. Farmers face numerous challenges in changing practices, so policymakers must shift agriculture research, extension, and efforts to support and accelerate the transition to crop and livestock integration. It is that there are approaches, such as science-based farming practices like mixed farming, that can protect farmers from climate change and help them become more resilient and sustainable in the long run. Continued research, development, and validation of crop-livestock integration technologies that improve agricultural productivity and food security, environmental stewardship, and rural life quality are required.

Farmers face numerous challenges in changing practices, so policymakers must shift agriculture research and extension efforts to support and accelerate the transition to crop and livestock integration. As those conditions shift rapidly over the next few decades, many farmers will be forced to reconsider some of their options, which may include opting for more productive, sustainable, and climate-resilient agricultural systems such as crop and livestock integration. The role of local animal genetic resources in smallholder crop and livestock mixed farming systems has had a positive impact on food security. Due to them having evolved adaptations to the continent's diverse climatic conditions and environmental pressures over time, and these traits have had appreciable value in sustaining food security in crop and livestock integration. [78] observed that crop and livestock integration can be studied from three perspectives: as a factor in land use change, as a result of individual management practices, and as a means of meeting farmers' multiple goals.

Crop-livestock integration has the potential to improve food security because of its ability to recouple crop and livestock production, which encourages resource use efficiency. Crop-livestock integration, according to several authors [79, 80, 81], has three goals: reducing the openness of nutrient cycles, following the industrial ecology rationale, organizing land use and farming practices to promote ecosystem services, and increasing farm resilience to adverse climatic and economic. Animal agriculture's integration into cropping systems has the potential to improve semi-arid agroecosystem functioning by altering biogeochemical processes and facilitating multiple ecosystem services such as carbon and nutrient cycling and use-efficiency [82].

Farmers can diversify their risk from single crop production by using mixed farming systems, using labor more efficiently, having a cash source for purchasing farm inputs, and adding value to crops or crop by-products. Combining crops and livestock has the

potential to maintain ecosystem function and health, as well as to help prevent agricultural systems from becoming too brittle or over connected, by promoting greater biodiversity and, as a result, increased natural resource base shock absorbency [83]. Animals help to increase food security by lowering the risks of seasonal crop failures and diversifying production and income sources in mixed agricultural systems [84]. [85, 86] classify crop-livestock systems based on the temporal and/or spatial integration of crops, grasslands, and animals, as well as their effects on nutrient cycling and ecosystem services. Many authors argue that crop-livestock complementarities and synergies can improve nutrient cycling and ecosystem service delivery in agricultural systems [87, 88].

The resource poor farmers should integrate their crop and livestock production to be more resilient to the effects of climate change. Smallholder mixed crop-livestock farming, which is a common source of income for the poor rural population, not only promotes environmentally sound agricultural practices in such situations, but also increases agricultural productivity and, as a result, food security. African scientists are being urged to provide foundational and transparent information to integrate crop and livestock production systems, so that smallholder farmers can adopt crop and livestock integration to increase agricultural production while maintaining food and nutrition security in the face of climate change and variability.

Plans for the future for successful implementation of in crop and livestock integrations requires organizational and/or institutional support to create new marketing opportunities in smallholders farming sector. Supportive government policies which include provision of small scale farmers with a capital base, markets, and educational services will improve the adoption of crop and livestock integration. However, changes in agricultural practices will occur only when economic, policy, informational, and behavioral barriers to adoption of these technologies are removed. While mixed farming has grown in popularity over time, there are still barriers to adoption due to a lack of investment, long-term awareness, producer skills, and market competition [77].

6. Use of imported animal genetic resources for climate change adaptation and food security

Do exotic breeds need to be imported to improve the performance of local animal genetic resources?' ' is an interesting question that has elicited a variety of responses from various scientific groups? Nonetheless, local animal genetic resources are the most abundant animal group, and the continent's rapid and continuing increase in demand for livestock products as a result of population expansion provides smallholder farmers with enormous market opportunities. High-output exotic animal genetic resources from temperate regions are frequently unprepared for the effects of extreme heat, high humidity, and malnutrition that prevail throughout much of the agro-ecological zones of Africa. Unless their management is changed to safeguard them, which more unlikely to happen in small scale animal agriculture, the issue of heat stress in this group is anticipated to get worse as a result of rising temperatures linked to climate change. Manipulating animal husbandry practices technically could be possible in favorable conditions, for instance by changing the animals' diets to heat-generating feed that is easily digestible and installing cooling technology like ventilation fans, water sprays, or misters. The costs of these steps, meanwhile, might be out of reach for majority of resource constrained rural farmers in Africa. With the aforementioned scenario it is unlikely that use of imported germ plasm would be the solution to the perennial food insecurity in Africa.

The genetic makeup of a breed, on the contrary, can be improved through within-breed selection or crossbreeding with high-performing exotic breeds, and total substitution of local genotypes with exotics can also be attempted [89]. In the case of higher within-breed genetic variation, however, it is critical to consider selection-based genetic improvement programs. However, when within-breed variation or heritability of

a targeted trait is low, crossbreeding or replacement of local animals' genetic resources may be explored. Due to the lower growth and reproductive performance of the local animal genetic resources, careful consideration must be given to improving their genetic makeup, which in turn maximizes productivity and production at the individual and national levels and is expected to address Africa's food security. There are 2 possible routes for improving the genetic makeup of targeted traits in local animal genetic resource. Secondly crossbreeding can be used resulting in rapid improvement by enhancing the genetic performance there have been more setbacks than merits of the genetic improvement of local animal genetic resources through crossbreeding with exotic breeds.

Crossbreeding should be assumed to be a versatile tool for local animal genetic improvement because it relies on breed diversity, which is unlimited on the continent. Despite the fact that crossbreeding and breed substitution promote rapid genetic changes, they have been found to be risky because they have been managed in Africa based on empirical trial and error. The use of highly structured crossbreeding systems has proven difficult, and initial productivity improvements in first-generation crosses, as well as the genetic integrity of indigenous breeds, have been lost due to indiscriminate crossing of adapted and un-adapted breeds (Leroy et al., 2016) [90]. The introduction of exotic breeds in addition to the failure of achieving their objectives (improvement), they have a negative impact in maintaining the diversity of the indigenous genetic resources. Crossbreeding failure has been associated with the crossbreeds' failure in smallholder farming sector characterized by extensive farming where the health management and supplementation of feeding is inappropriate, hence crossing or replacement cannot help in achieving the required results in productivity. The genetic resources used should be appropriate for the climate, feed, health, management, and other production factors. For specific cases, distinct strategies (such as breed substitution, crossbreeding, new breed development, and/or population improvement within local populations) may be used.

The credibility of crossbreeding programs is thought to be dependent on (i) continuous access to adequate breeding stock, (ii) opportunities for improved livestock to express their genetic potential (via environment and feed management), and (iii) integration within a reliable market chain (Leroy et al., 2016) [90]. All of these factors appear to be major constraints in the small scale livestock production sector, and they have presumably had a negative impact on the success of crossbreeding programs in Africa. In small-scale animal husbandry, there has been a fierce debate for decades regarding whether it is better to exploit imported genetics or use indigenous genetic resources for livestock growth. One method is to use genetic selection in breeding programs to boost resilience.

There has been a shift in livestock utilization toward exotic genetics for commercial production on a small scale farming sector. In this regard, farmers appear to recognize the significant disparities in performance between exotic and indigenous animal genetic resources, which should be considered in light of the farming environment and management level. Because of their genetic superiority over local animal genetic resources, exotic breeds have dominated the commercial sector, despite the fact that adverse environmental variables may have hampered their performance. As a result, crossing local animal genetic resources or replacement cannot help achieve the desired results unless it is practiced in a high intensive farming setting with appropriate health management and feeding supplementation, which is the really limiting factor in smallholder farming sector.

7. Climate change knowledge gap and sustainable use of animal genetic resources for climate change adaptation and food security

Africa experiences widening evidence gaps in addressing issues related to the impact of and responses to climate change, particularly in resource constrained small-scale

livestock production systems, which has a negative impact on food security. There are significant knowledge gaps that need to be filled regarding the trade-offs and synergies between food security, adaptation, and mitigation brought on by alternative transformation routes for smallholder agriculture, as well as the potential effects of policies on achieving these three goals [91]. Therefore, by conducting research and development on issues related to agriculture and climate change, it may be possible to close evidence-based knowledge gaps in regard to how climate change will affect small-scale livestock production systems, leading to increased livestock production and increased food security. The world is currently facing a number of challenges, one of which is climate change, which has a significant impact on food production and security, particularly in Africa.

Climate change's effects on agriculture and livestock have the potential to jeopardize food supply and security on a local and global scale. To make matters worse, the impact of climate change on agricultural production has complicated the issue of food security. The purpose of this opinion piece is to provide insight into the role of local animal genetic resources in the context of current climate change adversity as an opportunity rather than a disaster in enhancing food security. Evidence gaps exist in regard to climate change and small scale farming on the continent, which is relevant to the question of food security. To improve Africa's food security situation, evidence gaps in climate change on small scale livestock production must be closed.

The increasing challenge to ensure food security combined with the uncertain future in developing countries suggest strengthening animal genetic resources (AnGR) that are able to survive, grow, and reproduce in harsh environment. As a result, promoting local animal genetic resources is a long-term solution to the continent's perpetual food insecurity in the context of existing climate change adversities on agriculture. Many major food security issues have they relate to climate change and agriculture have insufficient evidence, and even when evidence does exist, it is sometimes insufficiently precise to be meaningful for meaningful intervention in small scale farming sector.

8. Africa requires morphological and molecular assessment of local animal genetic resources to promote food security

Animal breeding and genetic characterization of local animal genetic resources are tools to increase food security and lessen climate vulnerability. Local animal genetic resources are the continent's most important assets. The genetic diversity of local animal genetic resources should be investigated to establish the genetic knowledge base for successful conservation efforts and for selective breeding and utility. Determining the genetic variation among these resources and using the findings in breeding research is critical. Based on morphological features and molecular traits, the genetic diversity among genotypes of local animal genetic resources that are frequently used on the continent may be determined. At the molecular level, genetic markers could be utilized to determine genetic variety. The morphological characterization of genotypes reveals a wide range of morphological features among local animal genetic resources.

Climate change may pose a severe threat to the most sensitive breeds, putting animal production systems to the test and necessitating more conservation measures. Significant additional work is needed to characterize the phenotypic traits of local animal genetic resources, particularly in relation to survival, fertility, and performance in certain production situations, as well as their level of disease adaptation and tolerance or resistance [37]. Characterization studies on local animal genetic resources revealed that there was enough genetic diversity to support genetic improvement in Africa [92]. However, most genetic improvement has occurred on an adaptive level through natural selection within the challenging environment and production system in which these animals survive. Based on particular natural ecosystems, environmental conditions, and

socioeconomic factors, each living thing has the potential to develop particular genetic traits [93].

Local animal genetic resources are an important component of the rural agrarian economy in contributing food security and act as a critical reservoir of potentially useful genetics for future commercial strains and buffering rural areas from climate change adversity. The remarkable diversity of African livestock and avian genetic resources can be attributed to their evolutionary history and adaptation to environmental and human selection pressures over time, resulting in the formation of ecotypes animal species. Any future efforts to improve this genetic biodiversity on a continental scale will be contingent on understanding the genomic basis of productivity and adaptation to survival in smallholder animal agriculture systems in the context of climate change adversities, which will necessitate characterization.

For Africa the past two decades several studies have been conducted to identify, characterize, and describe the phenotypic variation of local animal genetic resource populations for different characteristics in both livestock [94] (Raya cattle) (Ethiopia); [95] (Nguni cattle) (South Africa); and avian species [96] (indigenous chickens) (Ethiopia); [45] (Indigenous chicken) (Kenya); [97] (Uganda); [98] (Morocco); [99] (indigenous chickens) (Cameroon); [100] (indigenous chicken) (Jordan); [101] (Local chickens) (Malawi); [102] (Village Chickens) (Mozambique).

External appearance (morphology) is still commonly used by researchers and practitioners in identifying farms, characterization and selection of animals to breed [103-106]. Observations on the outside view are the easiest thing to do, but the appearance of this morphology is heavily influenced by external environmental factors such as availability of food and climate [107-110]. The presence of animals caused by animal adaptation capability has the ability to produce more than one alternative form of morphology, physiological status, and or behavior as a reaction or adaptation to environmental changes in the form of regulation of gene expression and changes in shape phenotype [111-114].

As a result, selecting adapted animal species will be critical in maintaining productivity in this increasingly precarious environment. It is recommended that animal species that are adaptable to semi-arid tropics be identified in order to achieve sustainable levels of production, especially for smallholder farmers who are the majority. This is based on the assumption that selecting adapted livestock and avian species mitigates the negative effects of climate change, allowing productivity to be maintained and improve food security. Knowledge of genetic diversity and population structure is useful for developing effective strategies for improving farm animal genetic resource production, management, and conservation [115], which may be critical for sustaining food security in Africa. This provided insight into how both artificial and natural selection shaped the genomic variety of contemporary cattle breeds, which may provide the groundwork for further genetic investigations of livestock adaptability to tropical environments.

Natural and artificial selective pressures may have shaped the high chicken diversity and population stratification. Opportunities for complementary phenotypic and genotypic assessments to identify resources for effective breed improvement and conservation strategies of indigenous chickens in the tropics, on the other hand, have been discovered [116] reported in a related study in sheep that information derived from linear body measurements could be used to support genetic analyses to determine variation between and within small populations in order to develop effective conservation and utilization programs. Changes in breeding strategies can help animals become more tolerant of heat stress and diseases, as well as improve reproduction and growth development.

A potential climate-smart strategy to improve regional animal genetic resources and boost food security is community-based breeding programs. Local animal genetic resources have the potential to produce superior breeding formulations for community-

based breeding programs that are adaptable to local conditions, thereby improving food security. A community-based breeding program is a climate-smart initiative that improves local animal genetic resources while also increasing food security. Selective breeding within local animal genetic resources based on molecular biomarkers can improve specific attributes that are very appealing to small scale livestock farmers in severe climatic conditions exacerbated by climate change.

In this case, community-based livestock and poultry breeding programs could be strategically implemented across Africa to increase indigenous animal genetic resources while also ensuring food security. Modern livestock breeding procedures are generally unsuitable for poor resource farmers with small livestock populations dispersed throughout the neighborhood. In this scenario, farmer-scientist exchanges are ongoing in order to examine various breeding alternatives and so support informed livestock management decisions while enhancing productivity and food security.

Modern genomic science, including microsatellite DNA markers, the mitochondrial gene, and nuclear genes, must be used to improve our understanding of the genetic affinities of various animal genotypes in Africa because our understanding of the genetic variability and phylogenetic status of local animal genetic resources is still limited. In the future, investigations looking at diversity in a larger population of animal genotypes from various places may employ the genetic marker identification research to identify animal genetic variation at the molecular level in Africa. The results of such studies are anticipated to support current animal production and genetic resource conservation in Africa.

9. Indigenous knowledge and practices, climate change, indigenous animal genetic resources and food security

The livelihood strategy of resource-poor livestock farmers is heavily reliant on traditional knowledge, which serves as a reservoir for the wise management and utilization of diverse crop and animal genetic resources available at the local level [117]. However, the use of local ecological knowledge developed by farmers over time to adopt climate-smart agriculture practices has received less attention from researchers and policymakers [118]. Indigenous practices can help to improve and sustain agricultural crop land management, livestock production, climate change adaptation and mitigation, and agricultural innovation [119]. Furthermore, indigenous knowledge or practices on climate change adaptation and mitigation, as well as those focused on animal production and food security, will improve agricultural productivity and thus food security if properly synchronized with scientific evidence. Sustainable local animal genetic resource management is achieved not through animal rearing in and of itself, but rather through a combination of rural resource poor knowledge of their environment and livestock management.

For decades' indigenous knowledge practice have been vital in sustaining the utilization of local animal genetic resources while deriving the innovations for improving food security in the face of climate change in rural communities. There is a strong link between indigenous knowledge or practices, adaptation to the effects of climate change, and the use of local animal genetic resources for food security. Indigenous knowledge practice, when combined with evidence-based animal research, can increase productivity of local animal genetic resources and improve food security. To realize the full benefit of indigenous knowledge practice as a complementary aspect of animal production in rural areas scientific validation of this knowledge is critical. However, the rural population, which dominates agriculture and food production, is making frantic efforts to adapt to the environmental changes they see by utilizing local knowledge. Despite the fact that the role of indigenous knowledge of rural populations in climate change and adaptation response has received less attention from the outside world, it has served as a foundation for problem-solving strategies in agriculture where modern science is unavailable.

There is a growing body of evidence that rural farmers can use indigenous knowledge to cope with and adapt to climate change [120]. The availability and accessibility of scientific weather information to make animal production at community level continue to be critical issues in small scale rural farmers' use of climatic data. Indigenous knowledge, on the other hand, has been used by rural farmers but is becoming unreliable due to climate change and variability and this has offset agricultural production in general. Integration of indigenous knowledge and scientific seasonal forecasting appears to be a key possible thrust to reduce vulnerability, increase resilience, and increase adaptive capacity of rural farmers. Rural communities have been active in devising many adaptation responses to climate change through local knowledge systems, which are generally involved in adjusting animal production strategies.

According to [121], communities used a variety of coping strategies, with frequent livestock sales being the most common. Although underappreciated, local communities have their own innovative adaptation responses and practices; thus, focusing on the integration of this indigenous knowledge and complementary scientific endeavors should have the potential to limit the negative effects of climate change while also considering an alternative adaptation strategy to improve livestock production and food security on the continent. The incorporation of indigenous knowledge will strengthen the interdisciplinary climate change knowledge base, which will be extremely useful for climate change mitigation and adaptation in Africa.

[122] proposed the value of combining traditional and scientific knowledge in climate change and variability adaptation strategies. This on the backdrop that local communities live in close proximity to nature and are frequently the first to notice and adapt to its changes based on their local knowledge. As a result, combining scientific and indigenous knowledge in adaptation and coping strategies may benefit Africa with the most undeveloped technology. Droughts have a negative impact on subsistence agro-pastoralists in semi-arid rural farmers, according to [123], who employ a variety of coping and adaptation strategies in response. Due to the impact of climate change on water bodies several farmer-adopted strategies for conserving water in pastures, including the construction of spreader banks to conserve moisture in grazing lands, rotational grazing, and the use of ecological principles to maintain grazing lands and manage livestock units based on grazing land carrying capacity [124]. Such global monologue has frequently failed to take into account the valuable insights on direct and indirect impacts, as well as mitigation and adaptation strategies based on indigenous knowledge from resource poor communities in Africa.

Indigenous knowledge systems are more livelihood-oriented in managing local animal genetic practices; they primarily act on the risk-aversion concept by preserving the diversity of local animal genetic resources. Elsewhere, [119] observed the use of indigenous knowledge practices have positively increased milk production, fertility, placenta retention, repeat breeding, prolapse, newborn care, and the preparation of indigenous livestock products. On the disease treatment front indigenous knowledge on ethno-veterinary disease control has been prominent in most rural areas of Africa. Traditional knowledge, folk beliefs, skills, methods, and practices used to treat livestock ailments are studied in ethnoveterinary medicine. Under local knowledge systems plant-based remedies are still the most prominent, and sometimes the only, source of therapeutics in livestock disease management in rural areas.

Indigenous knowledge provides a foundation for problem-solving strategies in a variety of activities, including animal agriculture for food security, climate change mitigation, veterinary medicine or animal health, and general natural resource management. Hence it serves as the bedrock of any country's knowledge systems hence plays a critical complementary role of scientific evidence in characterization information can lead to formulation of sustainable utilization and in turn, conservation of local animal genetic resources for enhance of food security. This implies indigenous knowledge

practices and innovations derived from the utilization of local animal genetic resources must be integrated into relevant policies and climate change adaptation strategies at the local and national levels to improve livelihoods and food security. This indigenous knowledge system is crucial, not only in understanding the history and nature of existing diversity in animal populations, but also as a basis for developing strategies for its continued maintenance and sustainable exploitation (e.g. niche markets) in a way that accommodates the lifestyles, aspirations and livelihoods of the keepers [125].

Research on the effective use of local knowledge and practices, as well as the integration of locally feasible improved technologies with science-based aspects of animal production, are required to maximize animal productivity from local animal genetic resources and improve food security in the face of climate change. Understanding the utilization of indigenous animal genetic resources and local smart animal production technology reveals important ecological guides for the development of economically viable, environmentally sound, and self-sufficient alternatives for increased animal production to support food security.

10. Africa's future in animal genetic resources breeding and food security prospects in the face of climate change

The use of genomic tools to improve Africa's local animal genetic resources is critical if genetic progress is to be made, but their effectiveness will be determined by national and regional selection strategies, including animal breeding and genetics training and capacity building efforts. Within the framework of a formal strategy, genomic technology could benefit genetic improvement [92] thus increasing animal productivity and food security in Africa. Utilization of indigenous animal genetic resources in breeding and production has enormous potential for increasing productivity and contribute immensely toward food security in Africa if supported by appropriate policy and infrastructure and developing capacity in smallholder agriculture systems.

Animal breeding of local genetic resources is part of the solution to developing a resource and cost-effective strategy that is effective in reducing or eliminating environmental pressure, taking into account the need for climate change adaptation issues, increasing food security, and meeting the needs of the rural majority in the future. [126] suggested that incorporating non-market as well as market economic trait values in the aggregate genotype may enable breeding programs that contribute to sustainable production systems. A future with sustainable small scale animal agriculture can be created with the help of animal breeding, which will determine the many opportunities to improve the biological and economic efficiency of food production while also increasing food supply. Taking into account the three pillars of consumer, environmental, and economic sustainability, animal breeding of local animal genetic resources is inextricably linked.

The importance of genetic adaptation in small scale animal agriculture cannot be overstated. However, adaptation frequently comes at the expense of performance, and survivability is often higher in "low" performance animals due to lower input needs (especially feed) and internal heat production [127]. For Africa, it is critical that future animal breeding approaches consider both short-term and long-term benefits to improve adaptation and productivity, thereby contributing to food security. The diversity of adapted indigenous genetic resources used in small scale farming systems greatly contributes to animal related products and food security in Africa. To meet the growing demand for animal-related foods and maintain food security, small-scale animal agriculture production should increase while taking sociocultural, economic, and environmental sustainability issues into account.

The ability of an animal to survive climatic adversity is determined by its genetic potential [128]. Under the unfavorable effects of climate change, adaptability and genotype-environment interactions are critical for production and, as a result, food

security in Africa's animal breeding systems. In the context of climate change, Africa's breeding methods should be focused on the advantages of native animal genetic resources. Such measures can help future animal breeding methods generate high-quality genotypes that can thrive in harsh environments. The poor survival, growth and reproductive performances of the exotic animal genetic resources, in addition to being a threat in maintaining diversity of indigenous breeds, can lead us to choosing a more sustainable genetic improvement mechanism. In such situation, addressing the need for sustainable genetic improvement of indigenous resources can only be achieved through within breed selection.

Any decision making for the future genetic improvement efforts that account for climate change need to consider maintaining the diversity of local animal genetic resources for food security. This should not be a missed opportunity for Africa, given that local animal genetic resources have been shown to possess to some extent these adaptive characteristics and the only option is to perfect them through genomically enhanced evaluation. Apart from the development of strategies for incorporating knowledge from all genomic animal evaluations, it is vital to have knowledge breakthroughs in defining fine phenotypes for identifying heat-tolerant farmed animals. It should be noted that within population animal selection and systematic crossbreeding programs in developed countries has been a contributed significantly to strong gains in livestock productivity, and has benefited considerably from the fact that animal genetic resources in developed countries are well characterized.

Breeding objectives and programs for resource-constrained small-scale livestock systems are likely to differ significantly from traditional programs that have been successful in developed countries. If we want to see success in livestock breeding programs on the continent, we must develop breeding strategies that are uniquely African, taking into account the sociocultural, economic, and environmental fabric. Here are some of the errors that stakeholders make when looking for livestock improvement programs in Africa. Many animal breeding strategies that have worked elsewhere have failed miserably in Africa because stakeholders and funders have failed to recognize that Africa has a very different livestock production landscape and universe of discourse than the rest of the regions. Lack of attention to the smallholder farming sector or failure to tailor strategies may result in livestock improvement strategies overlooking valuable segments of local livestock production systems dominated by small scale farmers.

In Africa, livestock breeding strategies that lack flexibility are thought to fail hence using a strict animal breeding strategy is one way to ensure failure. Many African countries remain fragile and vulnerable to both domestic and international (social and economic) influences. As a result, when developing a breeding strategy in Africa, you must be aware of all sociocultural, economic, and environmental changes and be able to quickly adjust your initial livestock breeding strategy. If you don't, you'll almost certainly fall behind. Furthermore, animal breeding projects in Africa have been hampered by a lack of understanding of sociocultural, economic, and environmental nuances.

Approaches that are insensitive to sociocultural, economic, and environmental factors can be disastrous for livestock genetic improvement programs. Increasing your sociocultural, economic, and environmental understanding will boost the effectiveness of your livestock improvement projects. Hence the concept of Community Based Animal Breeding might need to be perfected as a solution to improve livestock genetics and enhance food security in Africa. Cross-breeding and substitution can speed up genetic change, although they may be more difficult to implement than pure breeding and call for further research (such as that on the interplay between genotype and environment) [129]. If performance-based phenotypic data are available, genomic selection has the potential to speed up both pure- and cross-breeding programs for adaptation. Long-term, very sophisticated technologies like genome editing and cloning may support conventional

breeding techniques to promote the growth of livestock populations that are better adapted.

11. Conclusions

A wide diversity of indigenous livestock and poultry breeds and types are abundant in Sub-Saharan Africa, and these animals have successfully supported food production in rural areas over the decades. However, governments have not provided the maximum amount of support to develop this sector, primarily because of misconceptions about their genuine value, therefore their entire potential has not been fulfilled to support food security. This is in light of the fact that indigenous animal genetic resources have endured in order to meet the food needs of the resource-constrained rural population in Africa, despite the harsh and extreme environment brought on by climate change, which is accompanied by animal diseases and parasite infections, heat stress on animals, installments of livestock feed, and water scarcity.

The welfare and livelihoods of rural people, as well as the security of their food supply and nutritional status, as well as other socioeconomic and environmental advantages, depend heavily on the local genetic animal resources. The local livestock and poultry husbandry among rural resource-poor farmers would be impacted by climate change in a variety of ways, including uneven rainfall onset and stoppage (each of which is either early or late), poor seasonal distribution of rainfall, and less rainfall than usual. The average temperature and rainfall have both shown rising trends. The main issue right now is how vulnerable this sector is to climate change, which has affected their capacity to maintain productivity in rural areas. In this situation, rural communities should be supported in their quest to implement coping mechanisms to stop animal agriculture's susceptibility in order to prevent food and nutrition shortages at the family level.

African agriculture is highly vulnerable to climate change; hence its food security is at crossroads. A determination should be made to cushion African agriculture from climate change and boost agriculture production to enhance food security in the long-term. One such determination is a paradigm shift onto investing in R&D and capacity building in utilization of adapted indigenous animal genetic resources to enhance their contribution to food security. In the advent of climate change any future strategy meant to address food security while undermining the use of adapted indigenous animal genetic resources will not be viable in the long term. Promoting indigenous animal genetic resources will cushion Africa from the devastation caused by climate change and variability if given the most attention, considerably boosting the security of the continent's food supply.

Climate change is here to stay and seems to be getting worse now and then. Disregarding adapted local animal genetic resources in the food security matrix the consequences are far fetching that the continent will either remain food insecure and hungry and an external food dependent continent or be more vulnerable to disruption from unforeseeable surge of environmental challenges as a result of climate change and variability. Despite being scientifically neglected, underfunded, and undervalued indigenous animal genetic resources have continued over the decades to support the livelihood of the millions of rural populaces in their communities of origin and custody in Africa. This alone should motivate Africa to safe guard and promote the use of indigenous animal genetic resource, and now it is more compelling than ever with advent of climate change. Therefore, it is reasonably to suggest that given adequate attention than before the already adapted indigenous animal genetic resources may surpass the current contribution to livelihoods and food security levels and might change the face of food security landscape in Africa. To mention a few species, indigenous goats and village chickens have shown overwhelming potential to contribute to food security in rural agrarian economies despite the prevailing climate change induced stressful environment impinging on animal production in general.

Over the coming decades, Africa's population is predicted to increase significantly without showing any signs of relief, which will increase demand for food. Despite the predicted rise in food demand caused by population growth and the consequent impact on food security, climate change will result in lower agricultural production. Hence, long-term climate mitigation strategies must be implemented in order to protect food production to feed the expanding population and maintain food security. This study suggests that the issue of food security in Africa can be resolved by intensifying the utilization of indigenous animal genetic resources by providing the necessary support through research and development, extension, and appropriate agricultural policies.

Since smallholder farmers are widely acknowledged to be the primary food producers in Africa, and are the custodians of indigenous animal genetic resources, any strategies that support this sector will have a positive impact on food production and the achievement of SDGs on the continent. According to the present study, the improvement of rural household food security, along with the continental effort to achieve SDGs, should be part of a deliberate and comprehensive plan to transform the utilization of indigenous animal genetic resources and smallholder animal production in general by 2050. This will bring about the prosperity, resilience, sustainability, and all other desired animal-related food production outcomes.

For Africa the most effective strategy for maximizing the potential of animal genetic resources is to use them in agriculture and food production to improve food security in a sustainable manner. The achievement of sustainable use would continue to support livelihoods especially the food security component while decreasing the long-term risk to the continued existence and essence of animal populations. African local animal genetic resource breeding can help to develop solutions that are resource and cost-effective, reduce or eliminate environmental pressure, are climate change-adaptive, are good for the health and welfare of animals, increase food security, and meet the needs of the rural majority in the future. A future with sustainable animal agriculture can be created with the help of animal production and breeding, which will determine the many opportunities to improve the biological and economic efficiency of food production while also increasing food supply. These opportunities are especially appealing from a sustainability standpoint if appropriate animal breeding strategies which are community based are used. Taking into account the three pillars of consumer, environmental, and economic sustainability, animal breeding of local animal genetic resources is inextricably linked.

In the face of climate change, providing sustainable food production and supply for Africa's rapidly growing population is a pressing issue hence the need to impart resilience into the food systems in order not to compromise agriculture productivity. Food production, food security, and nutrition are the most visible pressing issues that require immediate attention if Africa is to meet the SDGs. Given the current climate-change-induced adversity, local animal genetic resources (livestock and avian species) hold the key to unlocking small-scale animal productivity, deepening socioeconomic rural-urban integration, and strengthening rural small-scale animal agriculture resilience to shocks, thereby improving food security. This is despite the fact that little attention has been paid to this critical group of animal genetic diversity. Developing local animal genetic resource production capacity in small-scale animal agriculture can thus benefit farmers.

While short-term climate smart animal husbandry practices are valued, supporting and promoting native animal genetic resources should be part of a long-term strategy for Africa's small-scale farming sector to tackle the food problem aggravated by global warming. As a result, in order to define and sustain indigenous genetic resources as part of a long-term food security agenda, current molecular-based research must be integrated with population phenotypic data and sociological study to enhance the utilization of local animal genetic resources for food security. In order to meet its goals for food security, the developing world can help Africa by giving it access to or training in contemporary molecular breeding techniques. Africa should follow suit because genomic tools are

proving to be most useful for unique product traits and disease resistance in other parts of the world, so adoption of such technologies to improve local animal genetic resources will be welcomed but with caution. However, the success of such technologies has cost implications, and they must be adjusted to adapt to local conditions, where the majority of farmers are small-scale.

Africa do not need imported semen and/or embryos and live animals because this has been the major reason for loss of vital local genetic diversity on the continents. Supporting small animal agriculture through innovative smart climate approaches such as biotechnology and genetic advancements may increase animal production; however, these require financial support and should be tailored to smallholder livestock production. Importing and exploiting alien animal genetic materials is suicide for Africa, as crossing is the primary cause of the loss of crucial native animal genetic diversity, which will be necessary to protect Africa from the ravages of climate change. Africa may need to pool resources for such a historic initiative on nurturing local animal genetic resources, learning from the past experience when expertise, research funding and infrastructure were major constraints in addressing vital issues bedeviling the continent on animal production. The future success of rural poultry development initiatives will determine the total reliance of rural farmers on our native chicken breeds, which ultimately results in their commercialization. If this happens, a number of objectives will be met, primarily those that pertain to lowering global warming and its effect on animal production and maintenance of food security.

The discussion calls for a paradigm shift in rural development and food security measures, favoring native animal genetic resources and capacities over imported unadaptable genetic resources. Individual households and national awareness and responsibility for preventing the progression of climate change must increase to help mitigate the effects of climate change on agriculture especially small-scale livestock and rural poultry production. Combining these measures with potential changes in smallholder animal agriculture farming practices and technology may result in small scale animal agriculture remaining productive and optimally contributing to food security.

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