Chapter

Goat - A Sustainable and Holistic Approach in Addressing Triple Challenges of Gender Inequality, Climate Change Effects, Food and Nutrition Insecurity in Rural Communities of Sub-Saharan Africa

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Abstract

A goat-centered approach to farming can help shift rural agrarian households and communities toward gender-inclusive climate change adaptation in agriculture to enhance food security and nutrition in sub-Saharan Africa. Gender inequality, climate change, and food and nutrition insecurity are the most defining and deeply intertwined socioeconomic and environmental challenges in rural communities in this region. This chapter offers an overview of the potential of goat rearing as a sustainable and holistic approach to addressing these challenges. The failure to address gender inequality and climate change has thrown sub-Saharan Africa into a state of perpetual food scarcity due to compromised food production, consequently condemning rural communities and their people to extreme poverty and malnutrition. Because of this scenario, many internal and external development agencies have put several measures in place to alleviate the situation, which has long preyed upon the region and continues to frustrate food stability there. The total failure of the previous autonomous attempt to address the triple challenges of gender inequality climate change, and food and nutrition insecurity at the household level has led to the exploration and endorsement of more sustainable and multifaceted approaches. We propose that goat rearing is one such initiative, as it combines the empowerment of women in agriculture to ensure availability of the basic food needs of the household with sustained animal production due to goats' ability to adapt to harsh environmental conditions. The goat-centered multifactorial approach is focused on the exploitation of the interlinkages among these socioeconomic and environmental ills. The major assumption is that goat rearing in rural economies simultaneously curtails the risk of food and nutrition insecurity by acting as an entry point of gender equality while leveraging the opportunities that goat rearing will effectively offset adversities posed by climate change. In most instances, women are potentially more vulnerable than men, as they directly experience the adverse effects of climate change in agricultural production, in turn

compromising food and nutrition security. Goat rearing is central to the removal of systemic barriers that hold women back from equal participation in agriculture by broadening their socioeconomic opportunities, hence playing a significant role in agricultural value chains. The goat-rearing sustainability concept is based on establishing and maintaining the circumstances under which people and nature can subsist in productive harmony, which allows fulfilling the social, economic, and other requirements of present and future generations. Despite the adverse effects of climate change, the goat population has continued to proliferate in the harshest agroecological regions, which demonstrates that goats have managed to adapt to the current unfriendly environmental conditions. It is assumed that promoting goat rearing will narrow the gender equality gap between men and women and enhance the participation of women in agriculture, hence improving productivity and food and nutrition security. Goats, due to their large numbers and deep embedment in rural communities, have constantly contributed to poor rural farmers' livelihoods in many ways, and their contributions tend to be significant. This chapter reviews the potential of goat rearing as a sustainable and holistic approach to addressing the triple challenges of gender inequality, climate change, and food insecurity in rural communities of sub-Saharan Africa.

Keywords: goat-centered approach, gender inequality, climate change, food and nutrition insecurity, rural, sub-Saharan Africa

1. Introduction

A goat-centered approach to farming can help shift rural agrarian households and communities toward gender-inclusive climate change adaptation in agriculture to enhance food security and nutrition in sub-Saharan Africa. Goat rearing is a potential sustainable and holistic approach to addressing the triple challenges of gender inequality, climate change, and food insecurity in rural communities of this region. These challenges are deeply intertwined and are among the most defining socioeconomic and environmental concerns in rural communities' livelihoods. Since these challenges are interdependent, it is imperative to develop a sustainable holistic approach that integrates economic, social, and environmental variables to address them.

This chapter discusses the potential of goat farming as a sustainable and holistic approach to addressing the aforementioned challenges. Agriculture (crop and livestock) is a key livelihood activity, but it is vulnerable to climate change [1]. In recent decades, global awareness of the need to adapt agricultural systems and rural resource-poor livelihoods to the stressors emanating from climate change and variability has intensified [2]. In addition, gender, as a socioeconomic–cultural factor, has been applied to assess the roles, responsibilities, constraints, opportunities, and incentives of people involved in agriculture [3, 4]. Similarly, the awareness of integrating gender aspects into climate change action in the agricultural sector to enhance food security has been recognized. The disregard of gender-specific differences in adaptive and mitigative capacity allows climate change to worsen the existing gender inequalities in agriculture and beyond [5].

The question in this context is "How do goats fit into this matrix?" The frame of reference is that goat rearing is an integral component of a climate-smart livestock production strategy, acting also an entry point for gender equality [6]. The multifactorial role of goat "power" in sub-Saharan Africa first acts as an entry point for gender equality [7] and second as an agroecological zone-specific, climate-resilient, thermotolerant animal species that can sustain productivity [8] and enhance food

and nutrition security. The inherent small size of goats is beneficial for socioeconomic, managerial, biological, survival, productivity, and food security reasons [9].

Goats in rural areas have been deeply embedded in the socioeconomic and environmental fabric as a major livestock species that is rapidly increasing in number and is unlikely to change significantly in the foreseeable future [9, 10]. The unquestionable potential of smallholder livestock systems to sustain livelihood to billions of rural food producers and reduce vulnerabilities in rural resource-poor economies [11] renders goats an attractive option for pro-poor agricultural development agendas and enhancement of food and nutrition security. The diverse range of agroecological zones and management systems in sub-Saharan Africa where goats are reared despite the harsh environmental conditions is a testimony to their adaptability, and the assumption is that they will preserve their productivity and thus enhance the food and nutrition situation in rural areas. Most goats are kept in rural resource-poor agricultural systems, and their relative distribution is immense because of their comparative adaptive advantages over other animal species in most agroecological zones in sub-Saharan Africa. These systems, because of climate change, are never static but are constantly evolving with changing internal and external factors. Despite this, goats have continued to play a significant role in the food chain and overall livelihoods of rural households, which are largely the property of women and their children.

The inherent proficiency to rear, reproduce, and produce goats in adverse climate conditions is ascribable to their adaptive traits, as they proffer multiple products and services and benefit rural economies greatly [12]. This chapter presents an overview of the potential of goat rearing as a sustainable and holistic approach to addressing the triple challenges of gender inequality, climate change, and food insecurity in rural communities of Sub-Saharan Africa.

2. Material and methods

For this study, we conducted research using scientific papers, books, and statistical data from the United Nations to examine the interconnectedness of goat production, gender, climate change, and food security in rural economies in sub-Saharan Africa. The concept is based on the realization that the multifactorial role of goat "power" in this region acts as an entry point for gender equality and that goats are an agroecological zone-specific, climate-resilient, thermotolerant animal species capable of sustaining productivity and enhancing food and nutrition security in resource-poor rural areas.

3. Human and goat population trends and production and their implications for rural livelihoods in sub-Saharan Africa

In 2019, the estimated population of sub-Saharan Africa was 1.1 billion [13]. This number is expected to increase to 2–2.5 billion by 2050, which will drive the population density to 80 people per square km. It should be noted that the larger proportion of the population in the region dwells in rural areas and is mainly dependent on agriculture. Therefore, it is reasonable to assume that there will be more people to feed and thus there will be more pressure on natural resources. As such, there is a need to strategize a plan for enhancing food and nutrition security. According to [14], the projection in the Sub-Saharan African population increment is that it will double by 2050. The increase in the sub-Saharan population and the need to provide food for a growing population, compounded by novel consumption patterns, will

put a burden on livestock production systems and products [15–17]. This scenario is more compelling due to the advent of climate change, which obviously reduces agricultural production in general, especially in rural areas. As shown in **Figure 1**, it has been projected that sub-Saharan Africa will outpace other regions in population growth. **Figure 2** illustrates that the doubling of the human population as projected will likely pose a greater challenge to the rural population, as it makes up the greater proportion of the population in sub-Saharan Africa [14]. Similarly, **Figure 3** shows that population growth in rural areas outpaces that of urban dwellers in developing countries because of pressure on natural resources.

Livestock systems, as agricultural subsectors, are the major users of natural resources, which has a bearing on the relationship between agricultural production and resource use efficiency. Therefore, strengthening the role of livestock in rural areas is deemed a noble cause of sustaining the sub-Saharan rural food economies.

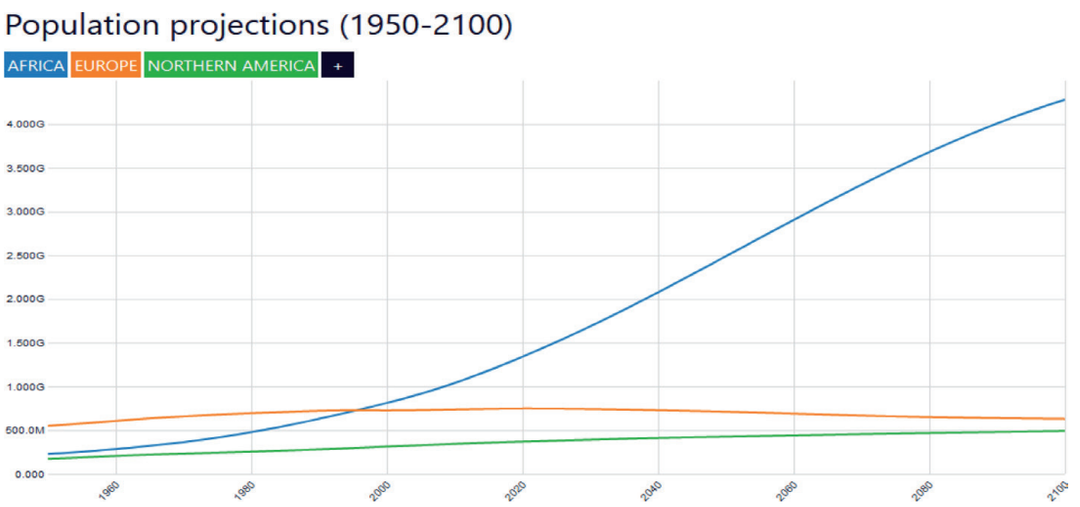

Figure 1.
Evolution of the world human population between 1950 and 2100 [18].

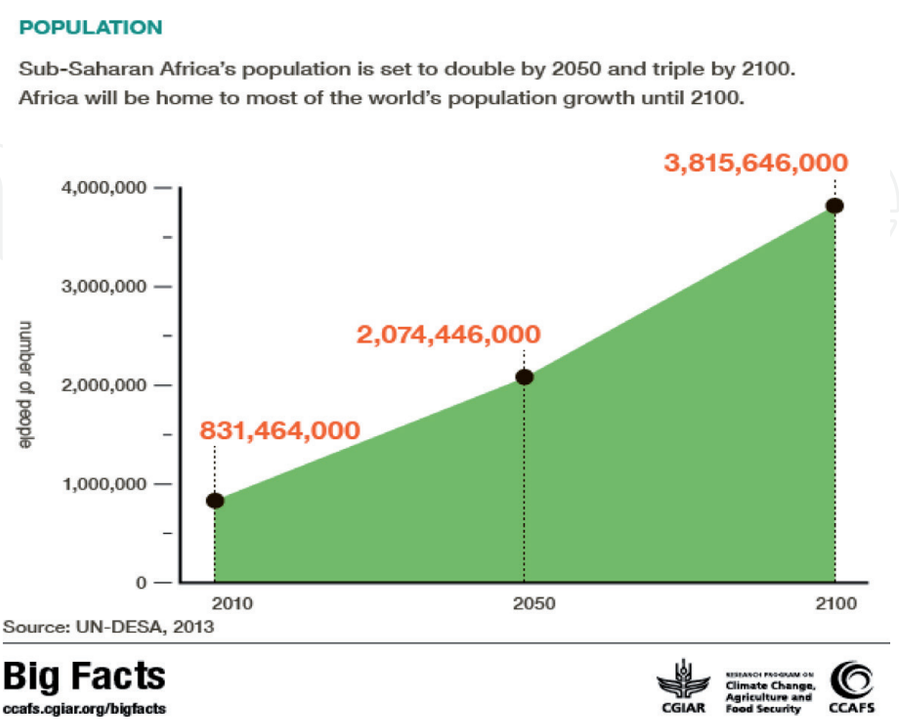

Figure 2.
Human population in sub-Saharan Africa (2000–2030) [19].

In this respect, the socioeconomic and environmental merits of livestock systems and how they contribute significantly to the livelihoods of at least 1.3 billion people in rural areas have been the focus of substantial public debate [10, 21]. **Figure 4** illustrates the increasing disparity between population growth and food production in sub-Saharan Africa.

Unless constraints on greater agricultural productivity are addressed, one-third of the population in this region will not have sufficient food by 2050. This indicates that regional poverty (**Figure 5**) and undernutrition (**Figure 6**) are rife in sub-Saharan Africa.

Figure 7 shows that the goat population worldwide increased steadily between 1994 and 2014. **Figure 8** illustrates the wider proliferation of goats in all the key agroecological zones of sub-Saharan Africa. In terms of world production, the share of goats produced by continental Africa is the second largest after Asia. This is an indication of the value of promoting goat production on the continent. Africa's goat population increased by 75% between 1980 and 2005 and constitutes 30% of the world goat population immensely contributed to the livelihoods of millions of rural economies [27]. FAO [28]

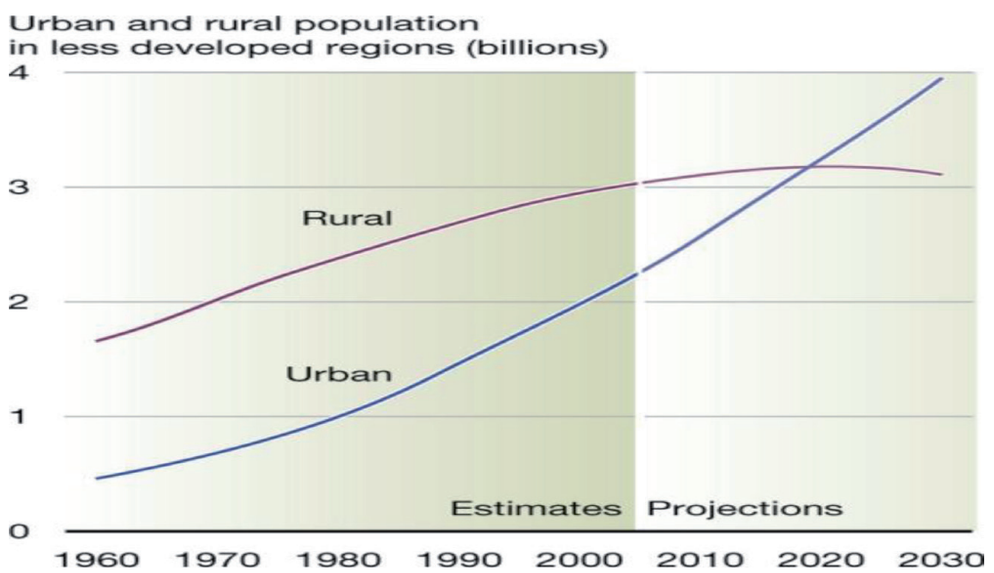

Figure 3.
Urban and rural populations in developing countries, 1960–2030 [20].

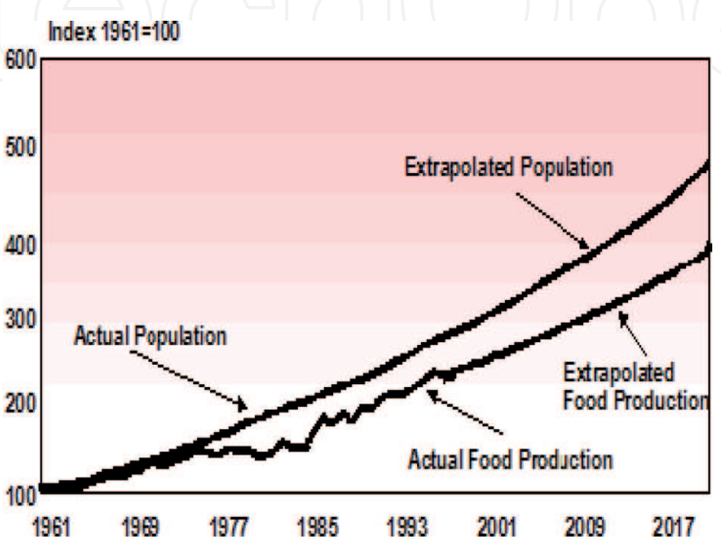

Figure 4.
Trends in human population growth and food production in sub-Saharan Africa [22].

approximated that the tropics and subtropics are home to 94% of the world's goat population. The reported livestock population of sub-Saharan Africa in 1999 comprised 182.1 million goats, [29] with approximately 64% located in rural arid (38%) and semiarid (26%) agroecological zones; more than 90% of goats in these zones are indigenous.

Despite these healthy statistics, sub-Saharan Africa has the second largest number of poor livestock farmers in the world. Poverty is rife on the continent (**Figure 5**), as are food insecurity and malnutrition (**Figure 6**). In sub-Saharan Africa, a greater proportion of the population remains undernourished, whereas Asia, the world's most populous continent, has a hunger ranking, as it is home to more than 526 million people [18]. Climate variability and extreme weather events are among the key drivers of the recent increase in global hunger and some of the leading causes of other socioeconomic and environmental challenges.

Figure 5.
Regional poverty [23].

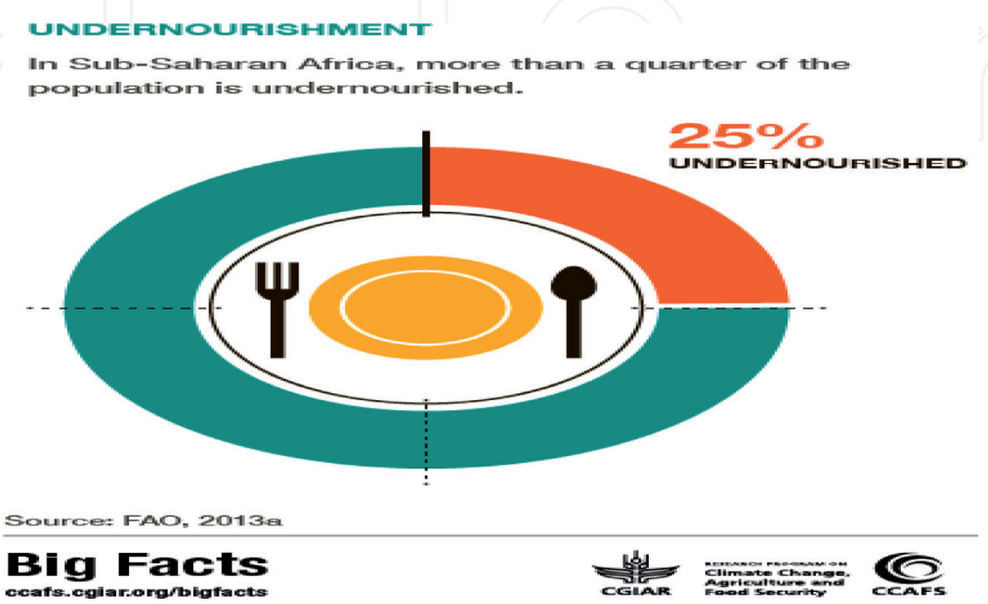

Figure 6.
Nutrition status in sub-Saharan Africa [24].

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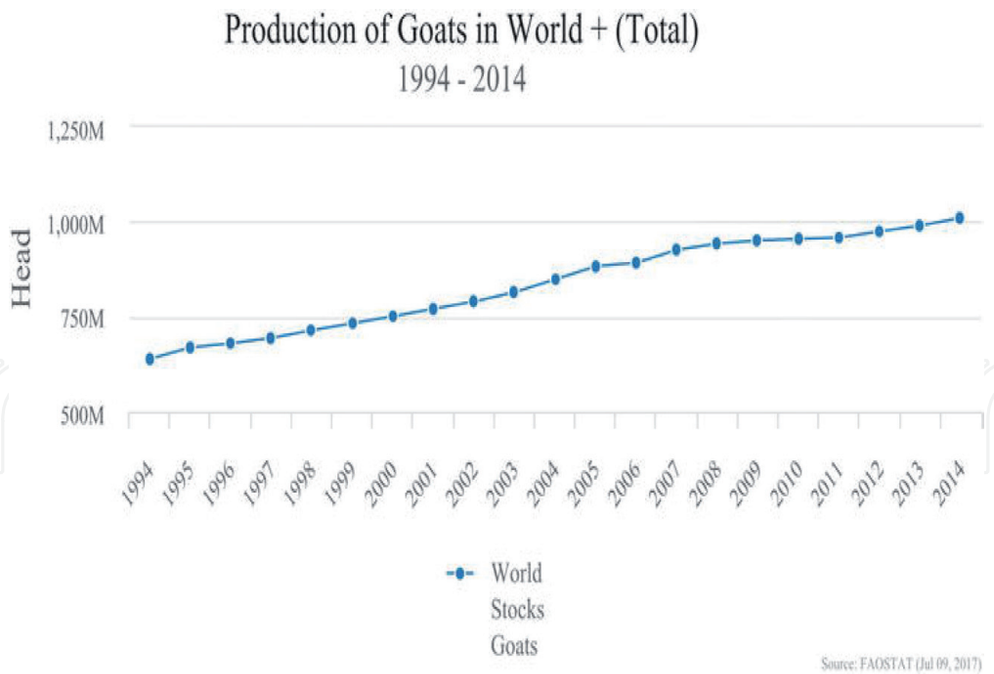

Figure 7.
Goat world population trends, 1994–2014 [25].

Figure 8 shows the adaptive potential of goats, which is clarified by the diverse.

worldwide proliferation across all key agroecological zones of sub-Saharan Africa from the tropical highlands to the humid regions and environmental interface.

Figure 9 shows that Africa is home to 33.1% of the world's goat population, and a greater proportion of livestock are reared by poor farmers (**Figure 10**). Goats in Africa account for approximately 36% of the total world population of grazing animals and are vital for the development of rain-fed, less-favored areas [7]. These systems, due to the effects of climate change, are never static but are constantly evolving with changing internal and external climatic factors.

The poor resource farmers in sub-Saharan Africa are highly vulnerable to climatic and environmental hazards, as their choices for resource diversification are limited. In some cases, vulnerability due to climate change has worsened due to disparities in engendered climate change impacts and response knowledge in agriculture. This solicit for clear response strategies from the point of view of mitigation and adaptation to address the threats posed by climate change.

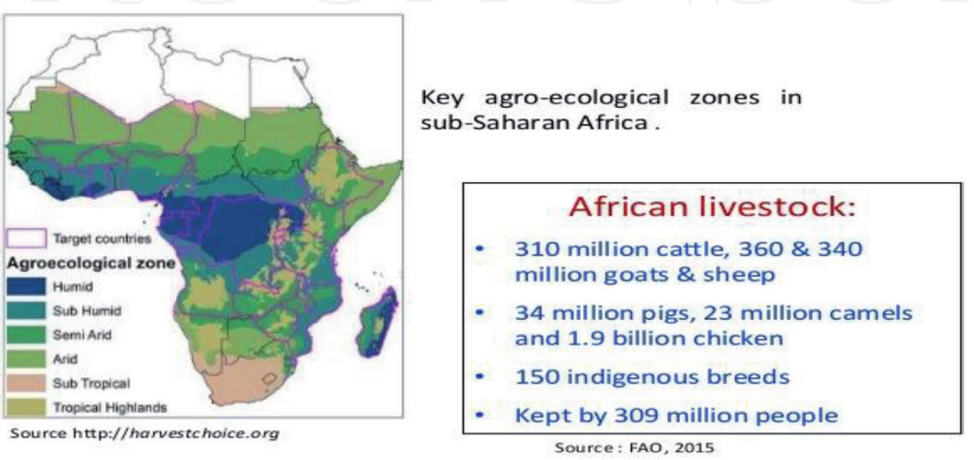

Figure 8.
African livestock and their agroecological zone in sub-Saharan Africa [26].

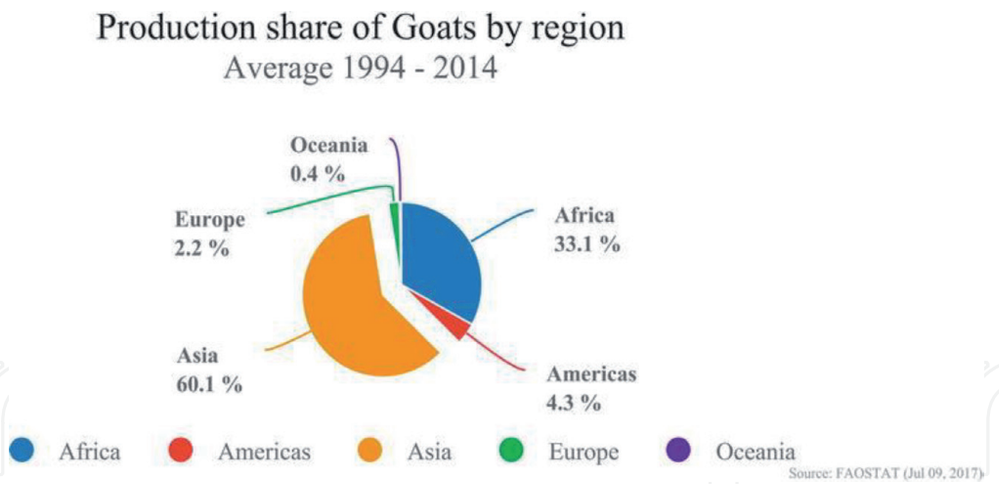

Figure 9.
Production of share of goats by continent [10].

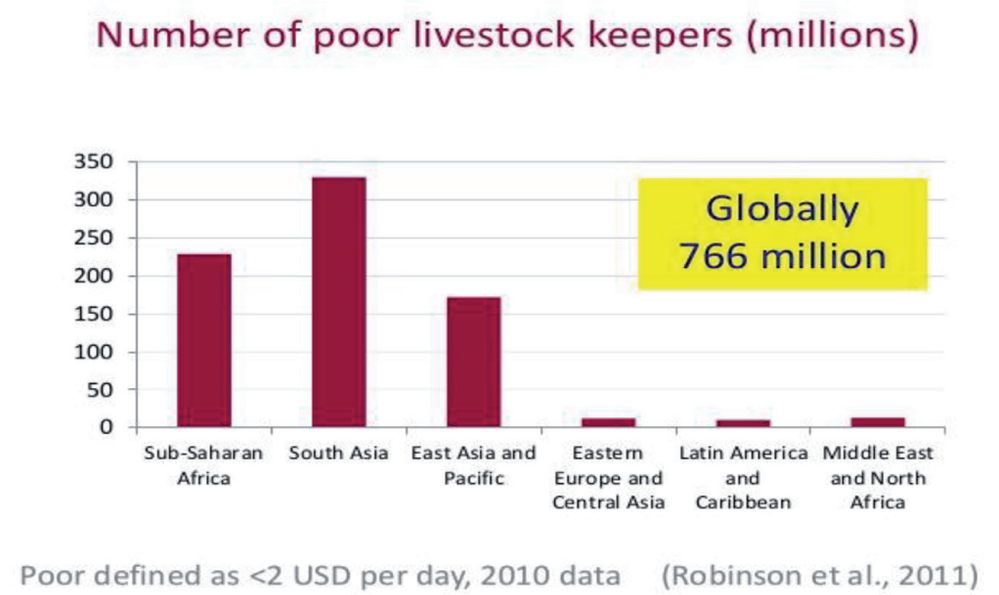

Figure 10.
Number of poor livestock farmers [30].

In this regard, the proposition of goat-centered mitigation and adaptation strategies that take into account gender relations but also curtailed the adverse effects of climate change variability and food security is called for.

4. Goat rearing: a potential strategy to mitigate climate change to cushion agricultural production and enhance food and nutrition security in rural economies in sub-Saharan Africa

Agriculture is the backbone of rural economies in sub-Saharan Africa and makes a significant contribution to households' food and nutrition security. However, despite agriculture sustaining livelihoods in rural, resource-poor farming sectors, it is one of the most climate-sensitive activities. Hence, it is imperative that mechanisms are put in place that protect the agriculture sector from the adverse impacts of climate change. At the same time, agriculture must mitigate its contributions to climate change (13.5 percent of global greenhouse gas (GHG) emissions come

from agricultural activity) [31]. As a result, mitigation strategies that are not only effective but also sustainable are needed. It is clear now that climate variability and change impact both crop and livestock productivity as well as people's livelihoods [32]. The influence of adverse effects of climate variability and change on rural agrarian households are anticipated to worsen in the future. The provision of coping strategies at agrarian households in addition to formulating appropriate agricultural-related policies will minimize these adverse effects.

Climate change is debatably one of the key challenges affecting sub-Saharan African countries, primarily because of the region's greater reliance on climate-sensitive sectors such as agriculture and inability to adapt to the changing climate [33]. Thus, there is a growing interest in devising strategies to cope with climate change effects on agricultural systems to avoid compromising agricultural productivity and enhance food security. In this context, we propose that goat production is a potential strategy to mitigate climate change effects in rural economies in sub-Saharan Africa. The practicability of this undertaking is based on the fact that the socioeconomic role of goat rearing has expanded during the last decades, especially in developing countries that are routinely exposed to adverse environmental conditions [34]. In addition, goats are an integral part of resource-poor animal production systems because of their short gestation period, high prolificacy, rapid growth rate, high feed conversion efficiency, high disease resistance capacity, and easy marketability.

The impact of climate change on goat production can be assessed by considering the direct or indirect effects of climate change on agriculture and food security. The direct consequences of climate change on agricultural systems and food security incorporate goats' structural, functional, and feeding behavior and their interaction with environmental conditions, as well as issues such as the optimal use of feeding resources, which is one of the major components that has been greatly affected by climate change. The elevation in ambient temperatures across continents due to climate change increases the vulnerability of rural agrarian households and communities due to perennial drought and food and nutrition insecurity. **Figure 11** shows the world average temperature variation from 1850 to 1900, and **Figure 12** illustrates the mean temperature increment for the past 100 years in Africa. The trends provide evidence of the reality of climate change, which in turn has a bearing on agricultural production.

Similarly, climate change's distortion of rainfall patterns consistently poses a threat to food and nutrition. It is common knowledge that rising temperatures and changes in rainfall patterns have a direct effect on agricultural productivity and

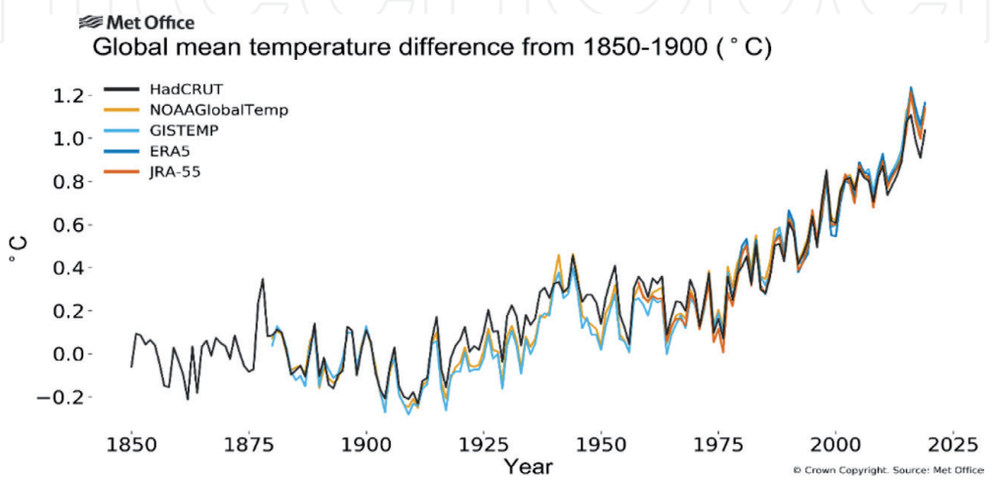

Figure 11.
Global mean temperatures 1850–1900 [35].

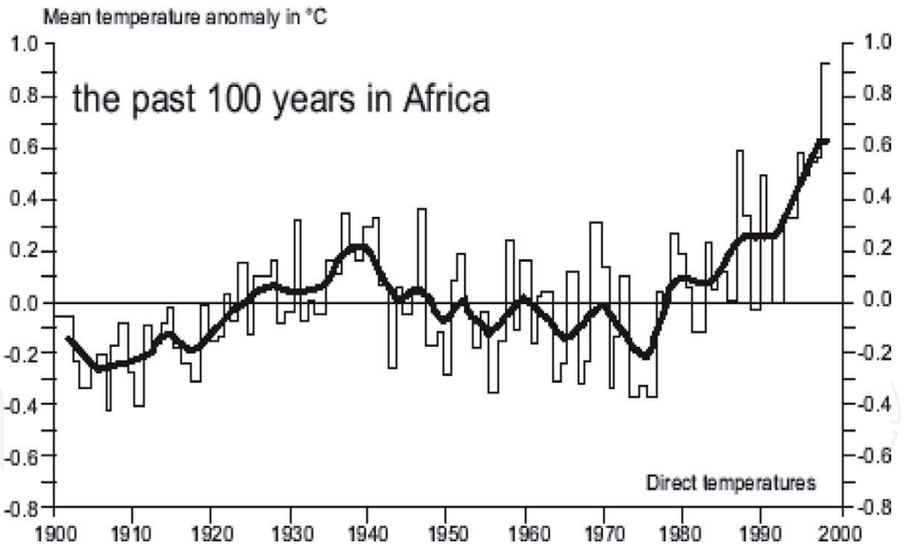

Figure 12.
Mean temperature anomalies in Africa (source UNEP, 2002).

food and nutrition security. However, the influence of these factors differs among various animal species, not to mention annual and perennial crops and agroecological regions of the world. Goat rearing as a sustainable and holistic approach to mitigating climate change and gender inequality is based on the notion that goats are relatively adaptable to the harshest agroecological regions and have the advantage of numbers. The largest share of goats is reared in rural agrarian systems, and their numerical distribution is vast because of their comparative advantages over other animal species in most agroecological zones in sub-Saharan Africa.

Climate change and variability are detrimental to general livestock production because they negatively affect the quality of feed crops and forage, water availability, animal and milk production, animal reproduction, and biodiversity, as well as lead to livestock diseases and parasites [36]. Despite all this, goats have emerged as an animal species of choice because of their ability to adapt to extreme and harsh climatic, geographical, and environmental conditions [37, 38]. Horst noted that goats have exceptional capacity to recover from drought because of their efficient reproductive behavior and variable body size [39].

One of the adverse effects of climate change on livestock rearing is grazing quality and quantity [40]. Under most rangelands where goats survive, forage has diminished over the years due to adverse climatic effects; therefore, the feeding behavior of animals has become critical. In this case, ruminants' energy requirements and digestive efficiency are vital criteria for selecting the most appropriate animal to rear in particular circumstances [41]. Aziz [42] observed that goats survive in differing ecological conditions, subsisting on different nutritional regimes under which they evolved and consequently sustaining their productivity. Principally, goat feeding behavior is intermediate and fixed, which favors both grazing and browsing, utilizing grasses in addition to shrubs [43]. In this venture, goats are extremely useful and effective in combating undesirable bush encroachment [44], which may be a dominant feature in most rural and poor communities.

Indigenous small stocks, such as goats, are much better adapted to local conditions than exotic stocks and require far fewer inputs for survival [45]. Of significance, goats have a greater capacity than other farm-reared ruminants to efficaciously convert poor feed resources into animal products such as milk and meat. The inherent complexity of goat structural, functional, and feeding behavior advantages has helped goat production under climate change-induced extreme

environmental conditions. Principally, the structural, functional, and feeding behaviors of goats play a critical role in enhancing production, reproduction, and survival in adverse conditions.

Multiple environmental stressors are a frequent occurrence in most rural agriculture systems in sub-Saharan Africa and will presumably increase due to climate change variability, which may depress agricultural productivity and food security [9]. In the ranks of climatic change stressors, heat stress emerges as the primary component that adversely influences livestock production. In this regard, goat rearing becomes vital to sustain livestock production and enhance food security. This does not coincide with the proliferation of approximately 41.5% of the goat population existing in harsh semiarid/arid areas in tandem with the continued syndrome of poverty adaptation-fragile livelihoods [7], which explains the ability of goats to sustain their production under climate change-induced extreme environmental conditions.

The concentration of goat populations in the harsh tropical and subtropical agroecological regions of the world demonstrates that they are more heat tolerant than other ruminant animal species [46]. In most cases, black goats are prone to minimizing energy disbursement in winter; nevertheless, they experience a greater solar heat load in hot conditions. Therefore, there is a need for breeding lighter coats in goats, as ambient conditions might progressively become hotter and drier because of climate change variability.

Goats, through alterations in behavioral, morphological, or physiological responses to changing environments, have managed to survive in various agroecological zones. As such, goat adaptation mechanisms in response to climate change are important because they open the possibility of finding a solution to animal adaptability to climate change and addressing agricultural productivity and food insecurity.

It is important to note that the survival of animal species is dependent on the species' ability to cope with or adapt to prevailing harsh climate conditions. To preserve animal productivity levels in an environment impaired by climate change, it is necessary for animal species to be genetically adapted with the ability to survive in diversified, harsh environmental conditions. Goats are among the animal species that can adapt to environmental heat stress by virtue of a composite of physiological, morphological, behavioral, and genetic characteristics. Their inherent physiological mechanisms allow goats to evolve in extreme temperatures with limited water resources [47]. Goats can repress the effect of high thermal stress by stirring behavioral responses, namely, feeding, water intake, shade seeking, and increased frequency of drinking.

Ambient temperature is a determinant of the feeding behavior of goats; hence, nocturnal feeding has been observed in goats, enabling them to avoid high temperatures during the day. In a related study [48], goats that were both heat stressed and water deprived actually preserved their milk production for 48 hours, notwithstanding a 20% decrease in body weight. This observation concurred with [49], who reported that despite elevated temperatures, goats never displayed physiological stress, and the mean values of magnitude reported were at the level of the limits of tolerance to heat stress. This is the likely reason goats maintained milk production.

Desert goats reared in accordance with traditional resource-poor systems were watered only once every 3–6 days, when water was scarce [50], and did not show much physiological stress. Studies of water deprivation in goats and other animal species in harsh environments are numerous and indicate that goats in West Africa, [51] East Africa, [52] and Southern Africa are more tolerant to water deprivation [53]. Feed intake was less influenced by water deprivation in adapted pygmy goats than in non-adapted breeds [54]. A report from [55] explained that goat tolerance

to water deprivation was ascribable to their ability to limit urine and fecal water excretion at high ambient temperatures. It is important to note that drinking behavior in animals is influenced by water restriction; in this case, there is a tendency of water deprivation in goats, predisposing animals to drink large volumes of water in one bout upon watering. This behavior is more distinct in goats than in sheep [56]. Such physiological behavior in goats will be critical in the advent of variability in temperatures due to climate change where temperature is expected to rise. This implies that to mitigate the effects of an increase in ambient temperatures due to climate change, promoting animal species with an efficient physiological response to heat stress is recommended. In this case, goats are inclined to tolerate heat stress better than sheep [57]. The tendency of most goats to have loose skin and floppy ears makes them more heat tolerant than other animals [58].

The morphological mechanisms that goats possess to minimize the effects of heat stress relate to their body shape and size, light hair color, lightly pigmented skin, and small amount of subcutaneous fat. Physiological means include increased respiration rate, increased sweating rate, reduced metabolic rate, and change in endocrine function [59]. This emphasizes the choice and use of adaptive animal species such as goats that preserve their production and are able to produce and reproduce in climatic-stressed environments. Hence, understanding how to confront climate change while protecting vulnerable rural communities through sustained agricultural production using adaptive species is essential to meet food requirements at the household level. This can only be attained through promoting adapted animals, and this is where the goat emerges as an ideal candidate.

An efficient reproductive system coupled with a small body size can easily adjust the flock size to correspond to scarce feed resources and water. It is important to note that it is easy to facilitate the integration or promotion of goats' rural communities because they are already embedded in the socioeconomic rural fabric. They can also be reared in limited space in addition to being popular with disadvantaged groups such as women.

Global climate change is primarily caused by GHG emissions that result in warming of the atmosphere [60]. The livestock sector contributes 14.5% of global GHG emissions; however, in ranking, goat production is known to emit relatively less methane than other domestic ruminants. Within animal production, the largest emissions are from beef followed by dairy and largely dominated by the methane produced during cattle digestion. The next largest portion of livestock GHG emissions is from methane produced during enteric fermentation in ruminants, a natural part of ruminant digestion where microbes in the first of four stomachs, the rumen, break down feed and produce methane as a byproduct. Methane is released primarily through belching. The status of goats relative to global GHG emissions will relatively address the challenge of maintaining a balance between productivity, household food security, and environmental preservation [61] in rural economies in sub-Saharan Africa. Indirect effects consider limitations on goat production from socioeconomic and environmental perspectives, which are mainly intended for decreasing GHG emissions, hence goat rearing has merits for rural economies' adaptation to climate change and addressing the pertinent issue of food insecurity.

Arguably, regarding mitigation, the improvement of animal nutrition and genetics is essential because enteric fermentation is a major GHG emitter in livestock production. Climate models predict that without substantial reductions in GHG emissions, global temperatures will continue to increase, causing major changes in our weather patterns, environment, and way of life. Therefore, in this case, selection of adaptable animal species such as goats that maximize feed efficiency, increase fertility, and improve overall flock health within the confines of adverse effects of climate change is recommended [59].

Worldwide, considerable efforts have been made by international organizations and governments to battle climate change and ensure food for needy populations [61]. The present discussion offers an overview of the impact of climate change on the livelihoods of rural farm households and the adaptation strategies used to cope with the effects of climate change on agricultural production and food security. To thoroughly explain the interlinkage between climate change and agriculture is a hypothetical matrix (**Figure 11**) where notable consideration has been paid to gender dynamics and climate change; the focus is to try and explain how gender issues and adaptation strategies are interrelated in rural households that are exposed to climate-related adversities that impinge on agricultural production and food security and nutrition. The discussion exposes a visible linkage between gender relations and climate change adaptation in rural agrarian communities.

Women are more vulnerable to the harmful effects of climate change than men, which has compromised agriculture and food and nutrition security. This is because women are the major players in rural agrarian agriculture. This trend is worsened by social norms and customary laws that promote gender inequality in rural agrarian households. The discussion proposes that goat rearing is an entry point for gender equality while protecting women from the effects of climate change on agricultural production and food and nutrition security. The discussion uses a hypothetical conceptual matrix, focusing on the interplay between gender relations and climate change adaptation as a subsector of the matrix. The overview concludes that adaptive capacity can be enhanced through the advancement of gender equality and women's empowerment through climate change knowledge and the promotion of goat rearing.

Poor resource livestock production systems, due to their reliance on specific climatic conditions, will in turn translate to the overall climate change effects impinging on productivity and food security. In this case, goats' adaptive features will provide an effective solution to livestock production systems as a way to mitigate climate change. As climate change emerges as pivotal in shaping future livestock rearing systems and their performance, it will have more influence on what livestock species to raise. In this case, the choice of agroecological zone-specific, climate-resilient, thermotolerant species to sustain livestock production and enhance food security is imperative in sub-Saharan Africa. This is based on the premise that the choice or selection of adapted livestock species such as goats will be part of a strategy to offset the adverse effects of climate change on livestock production while preserving animal productivity, which in the short or long term sustains food security. The development and promotion of goat rearing is a viable option in the context of climate change mitigation where other animal species seem to be relatively vulnerable.

There is the possibility that as adverse climate effects continue impinging on rural livestock production, goat rearing will assume a critical role due to goats' numerical strength and adaptive features such as feeding behavior and disease and heat tolerance, which gives them a comparative advantage for survival in harsh environmental conditions. In this regard, goats, due to their plethora of adaptive traits, emerge as a key facet in offsetting the destabilizing factors related to the uncertainties of climate change effects. Their ability to survive, reproduce, and produce in harsh environmental conditions is sufficient evidence for goats' capacity for sustainable utilization in resource-poor farming communities. As indicated by their numerical proliferation in sub-Saharan African's differentiated agroecological zones, goats have irrefutably proven that there are resilient livestock genetic resources that can be utilized to offset the effects of climate change and promote livestock production for increased food resources. Due to water scarcity, goats have the capacity to walk considerable distances in search of water and forage and make use of poor forage for their production and survival.

In view of this, rural, resource-poor production systems could be sustainable only in the long run if adaptive animal genetic resource species such as goats are promoted to offset adverse environmental effects and preserve performance levels. Goats' adaptation characteristics are embedded in their genetics, which implies that they are inheritable and favor the survival of goat populations in harsh environmental conditions. It is important to note that the climate resilient potential of goats is influenced by both phenotypic and genotypic characteristics, and there are several candidate genes that are highly associated with the adaptation of small ruminants to heat stress. Therefore, species and/or breed selection focusing on resilience is a worthwhile tool for sustaining animal production in an increasingly challenging environment [62]. Of interest is that some animal species tolerate heat better than others, which may be critical in the choice of species to raise in the harsh climatic conditions of rural economies. Goats are less susceptible to environmental stress than other domesticated ruminant species [57].

5. Goat rearing - a potential strategy in addressing gender inequality while sustaining animal production and enhancing food security in rural economies

Food and nutrition insecurity is a socioeconomic, environmental, and political subject; nevertheless, first and foremost, it is a gender issue that has resulted as a major cause and an outcome of compromised food production, food insecurity, and nutrition. Closing inequality gaps between females and males in food production systems will enhance women's ability to make themselves heard and direct the course of their own lives [63]. There is overwhelming evidence that indicates a strong correlation between gender inequality, agriculture, and food and nutrition insecurity [11]. Social and economic inequalities between men and women undermine food security and hold back economic growth and advances in agriculture [28]. It has been acknowledged that livestock production is one of the core sectors to address perpetual food scarcity and to bring future food stability to sub-Saharan Africa [64]. Microlivestock such as goats have emerged as integral livestock subsectors, apart from their adaptability to harsh environmental conditions induced by climate change, and have enormous potential for enhancing animal production, consequently enhancing food security in rural communities [65].

Goat rearing emerges as an appropriate conduit for enhancing food security and rural livelihoods, in addition to acting as an entry point for gender equality and the empowerment of rural women [63]. Turner [66] supported that women play major roles in rearing sheep and goats; hence, any developmental projects in this area will empower women in food production and nutrition. It has been noted that failure to identify agricultural subsectors where women are effectively engaged, such as goat production, has been the major reason for the unsuccessful nature of most of the development initiatives on food production and security in rural economies [67]. In the same study, it was observed that livestock development projects fail partially because the roles of women are neglected in the planning process.

The goat is the animal of choice for purposes that are within the domain of women's participation and responsibilities; hence, any goat-centered approach in rural development will consequently improve the lives of women in addition to enhancing food production overall. In most cases, due to increasing populations, the capacity for large ruminant animals, for example, cattle and buffaloes, has decreased; in this regard, shifting focus to micro livestock, such as goats, which are prolific and easy to manage, is recommended. Goat rearing in rural communities is one of the major components of livestock production systems in which women can

be empowered and improve household agriculture, food, and nutrition. Goats have continued to play a significant role in the food chain and overall livelihoods of rural households, where they are largely the property of women and their children [45].

Goat rearing acts as an avenue to improve women's capacity to develop as productive members of society while elevating their economic empowerment. In this case, goat rearing acts as a gender-transformative intervention that is decisive in building resilience and coping mechanisms among women and helps reduce vulnerability and improve food security and nutrition [67]. Quinsumbing et al. [68] observed that a reduction in the gap between men and women with respect to ownership of resources, decision making, and control is necessary for attaining food security. Women's lack of participation in agricultural activities and general engagement with other community activities is symptomatic of entrenched norms and broader gender inequities. The shift in policy that acknowledges women's critical role in food production and nutrition security has resulted in increasing women's productive and economic capacity. However, there is a need to further examine the root cause of the entrenched gender inequalities that prevent women from fully participating, in agriculture and food production.

Gender inequalities in rural communities are prevalent and will persist because of a range of intertwined social, economic, and political factors that need to be addressed holistically. There is a proliferation of engendered development studies claiming the merits of focusing agricultural investments at women, especially in sub-Saharan Africa [69]. The argument is that increasing women's empowerment will translate into an overall increase in agricultural productivity, hence reducing poverty and food insecurity. This notion is based on the premise that addressing food security requires more than the initiation of opportunities for individuals to earn sustainable livelihoods; it also demands the creation of a conducive environment for men and women to acquire those opportunities.

Achieving gender equality and women's empowerment is critical to the success of addressing food insecurity. It has been proven that gender inequality has translated into a loss of opportunities or potential gains in livestock production and food security. Goat production, as a subsector of agricultural production, helps poor households increase their food security, reduce their vulnerability, and start a process that will move them out of poverty [70]. Regarding gender-cognizant perceptions of food security, it has been debated that gender-blind diagnoses of the challenges of food insecurity result in inadequate policy responses, which culminate in the perpetuation of food insecurity. Effective and promising strategies to address food insecurity need to be gender-just and environmentally sustainable in the long term.

Studies have proven that gender inequalities do not merely compromise not merely the capacity to produce and acquire food for good measurement of the nutritional security of that food, which is so central to household welfare [71]. Gender mainstreaming in agriculture has been proposed as an indispensable strategy for attaining gender equality and food security. However, this takes into account that agricultural growth is a key pathway toward addressing development issues such as food and nutrition insecurity and poverty, all of which climate change is already exacerbating [72]. There is conclusive evidence that when women are granted broader opportunities to participate in agricultural activity, the benefits expand far beyond themselves as individuals to their families and communities to societies and economies at large [28].

The development and promotion of goat production directs an ambitious path toward enhancing opportunities for women because it is critical to individual household welfare and socioeconomic development. Goat rearing as a strategy in addressing gender inequality builds on solid evidence that long-standing gaps

between men and women impose real and significant disparities that need to be addressed. Since goat rearing is an important agricultural activity in rural economies of sub-Saharan Africa, its development and promotion is a promising intervention that can achieve tangible community results that can reorganize rural economies and positively address gender inequality.

There is overwhelming evidence that the provision of opportunities to women to partake in agricultural-related activities has positive effects on their families and communities in the form of improved household health, nutrition, and disposable income [63]. Advancing women's participation and control over micro livestock, which includes goats, supported by training in husbandry and animal health, in addition to increasing access to education, veterinary, and financial services, is essential to improving households' food security and nutrition.

6. Interconnectedness matrix: goat production, gender, climate change, and food security in rural economies in sub-Saharan Africa

Figure 13 models the interconnectedness of goat production and gender, climate. change, and food security in rural economies in sub-Saharan Africa. Responses to climate change tend to focus on scientific and economic solutions, disregarding the critical importance of human and gender dimensions. Gender relations are still largely absent from debates on climate change and animal production-related issues. Generally, all inequalities often contribute to environmental change, and transforming them is therefore an indispensable part of a more effective and sustainable strategy to build resilience. This implies that addressing gender differentiation in livestock production and disparities in climate change and response knowledge will facilitate sustainable community resilience.

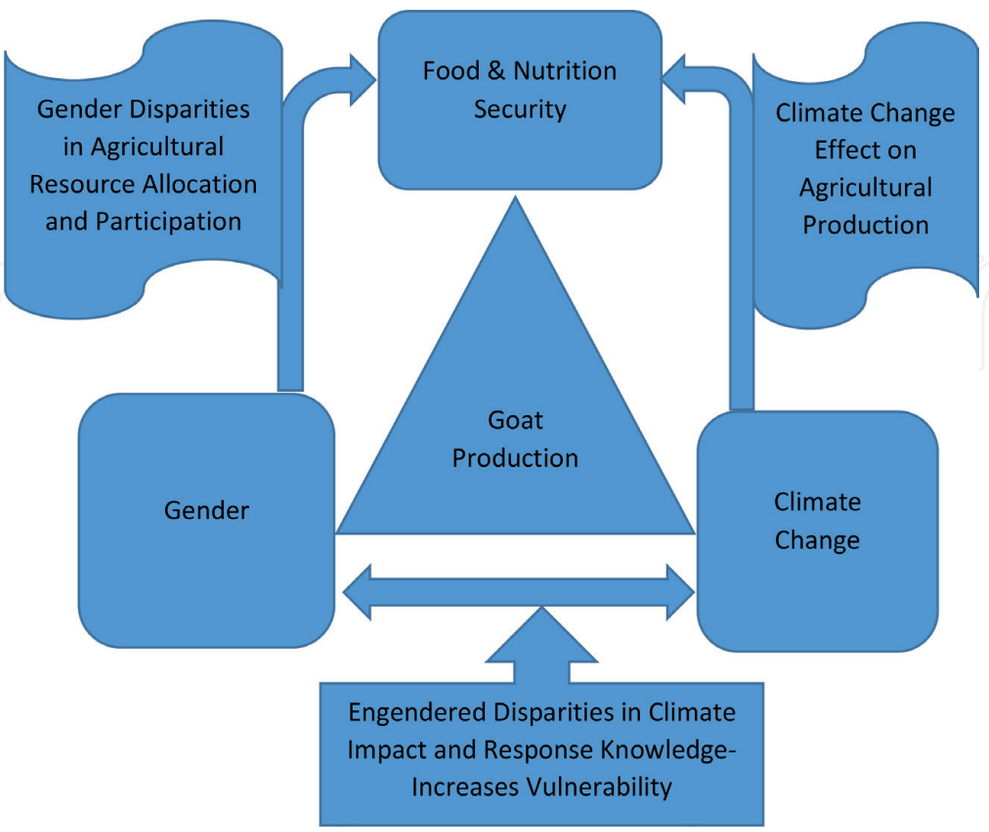

Figure 13.
Goat, gender, climate change, and food and nutrition security matrix. Source: Author.

This sustainable and broad-based approach to gender, climate, and food and nutrition security takes into account the complexity of social, economic, and ecological aspects of rural agrarian communities through adequately acknowledging the interrelationship of these factors. This understanding has a provision of the development of gender-sensitive goat production policies that fit with complex livestock livelihood strategies, especially for resource-poor livestock keepers' households. The matrix applies a gender perspective for understanding how goat production can be a pathway to food security possible through scrutiny of other elements such climate change and its impact on food security. Matrices are being modeled to explore different aspects of goat production, such as goat adaptability to adverse climatic conditions and less exposure to goat parasites, which makes goats an appropriate candidate for climate change mitigation strategies.

The two assumed goat production pathways out of food insecurity, climate change, and food security are (1) understanding disparities in livestock resource allocation and equal participation of men and women in goat productivity to address gender inequality and enhance food security, and (2) manipulating impact and response knowledge to reduce community vulnerability to climate change effects, thus increasing and sustaining goat productivity to address food insecurity and gender inequality. A general phenomenon is for men to own large livestock and particularly work animals, while women own micro livestock.

Strategies meant to enhance women's access to and control over agricultural resources or other assets have resulted in the enhancement of food security as well as the wellbeing of women themselves [65, 68, 73]. Men and women often manage different types of animals and are responsible for different aspects of animal care. Given women's traditional responsibility for household food security, their level of control over decisions about whether to sell or consume the family's animal products, as well as how to use any income obtained from the sale of animal foods, could greatly determine the nutritional wellbeing of household members.

For each pathway, the findings are organized around key questions about the role of women and lessons about interventions targeting women. Assembling this information is a first step toward identifying some of the main gaps in our evidence base as well as some of the kinds of research and development interventions made in which species and value chains are most likely to benefit poor women and their families. Women play an important role in livestock management, processing, and marketing, acting as care providers, feed gatherers, and birth attendants. Despite their considerable involvement and contribution, women's role in livestock production has often been underestimated, if not ignored.

There are potential effects of a goat-centered approach in shifting rural farm households toward gender-inclusive climate change adaptation to enhance food security and nutrition in sub-Saharan Africa. Regarding the matrix (**Figure 11**), the dependent factors of gender, climate change, and food security are deeply intertwined; hence, placing goat production as a redress factor, the matrix becomes an engendered livestock-based food security model that takes into account the adverse effects of climate change. The matrix is a departure from numerous previous hypothesized discussions that have focused on addressing gender inequality, food insecurity, and climate change adversity variables as isolated entities. This has posed challenges because these aspects of the socioeconomic and environmental nature of communities are interdependent, hence the need to establish a holistic approach in addressing these adversities. The matrix (**Figure 11**) is based on the understanding that goat rearing in rural economies will simultaneously curtail the risks of food insecurity and gender inequality and capitalize on the opportunities to offset adversities posed by climate change.

Gender differences in livestock production and disparities in climate change impact knowledge, and responses are the underlying root causes of vulnerability and food insecurity in rural communities in sub-Saharan Africa. Agriculture is a key livelihood activity, but it is vulnerable to climate change [1]. There is overwhelming documentation that climate change has a serious adverse impact on agricultural production and the livelihoods of millions of farmers, which has changed the lifestyle of rural people worldwide [74]. In recent decades, global awareness of the need to adapt agricultural systems and rural resource-poor livelihoods to the stressors emanating from climate change and variability has intensified. In tandem with this awareness, the importance of integrating gender aspects in climate change action in the agricultural sector has been recognized. Therefore, climate change discussion should afford adequate attention to gender-differentiated roles and vulnerability, in view of the fact that the impact of climate change has different implications for men and women. Lambrou and Piana [75] reported that women and men experience climate change impacts differently due to their socially constructed roles and responsibilities. Hence, it is imperative to design interventions that consider gender roles and guarantee protecting both men and women from the negative effects of climate change. This is based on the understanding that both men and women have a critical function to play in agriculture; hence, acknowledging gender distinctions facilitates appropriate, targeted interventions that offset vulnerability to climate change and contribute to gender equality and food security [74].

Assessment of adaptation, vulnerability, and resilience of communities against climate change and variability in rural communities can be applied using gender as a socioeconomic variable [76]. In most cases, there is a missing link to the scientific assessment of climate change impact through a gender integration approach to effectively mitigate and adapt to its impact. Consideration of the gender dimension in climate change is anticipated to culminate in effective interventions assisting both men and women in dealing with the impacts of climate change and bringing about resilient and comprehensive food security systems. Men and women can be effective agents of change with regard to environmental mitigation and adaptation only if they have equal access to information on climate change response. This implies that empowering men and women with climate change response knowledge can effectively advance sustainable agricultural production in rural communities as a result of offsetting the impact of climate change and enhancing food security. The provision of men and women with extensive theoretical and practical knowledge of climate change effects on agriculture should be given high regard. Broadening their role as agents of change in climate mitigation should be an integral part of the intervention strategy, and this aspect needs to be sufficiently exploited. However, the impact and response knowledge should be accurate and available to the general populace to accommodate anticipated changes.

Climate change is recognized as a global crisis, but responses tend to focus on scientific and economic solutions rather than addressing the vitally significant human and gender dimensions. Because of gendered social roles, women are in the front line of climate change impacts, such as droughts, floods, and other extreme weather events, yet they are the least responsible for environmental destruction. How then do we move toward more people-centered, gender-aware climate change policies and processes? How do we both respond to the different needs and concerns of women and men and challenge the gender inequalities that mean women are more likely to lose out than men in the face of climate change? The matrix helps to intervene through engendered climate change and food security perspectives to address the wider issues of voice, representation, and participation in general livestock production and decision making in rural communities.

The three pillars of this matrix are based on the acknowledgment of social, environment, and economic dimensions that influence rural communities, which are critical in discussions of gender inequality, food insecurity, and climate change vulnerability. The triple challenges seem to pose high social, environmental, and economic costs and lead to immense food insecurity in rural economies. The adoption of a goat-centered approach assumes that goat production is a predominant agricultural activity for livelihoods of rural communities in sub-Saharan Africa. The matrix provides avenues for pairwise analysis between subsectors such as gender and climate, gender and food security, and climate change and food security. Therefore, it is imperative that explicit attention be given to these relationships and how these dovetails affect goat production. An attempt to proffer a holistic approach that integrates scientific, technical, and economic aspects of goat farming with social and human dimensions is the major aim of this matrix.

Goats are deeply embedded in almost every sub-Saharan African rural economy and are a major agricultural subsector for most resource-poor farmers that can be exploited in addressing gender inequality, food insecurity, and climate change. However, it is important to note that the holistic perspective on these challenges is difficult to write about because of their direct and indirect connectedness. The matrix attempts to illustrate this phenomenon of the interconnection of gender, climate change, and food security.

The numerical status of goat species and composition in rural communities are critical to acknowledging trends in livestock ownership in rural economies and their impact on the vulnerability of resource-poor households to climate change and food insecurity. However, this matrix takes a holistic approach that is more difficult to achieve due to a variety of factors. Thus, it is imperative to improve our understanding of how the interaction of gender and climate change affects food security, particularly in resource-poor rural communities. It is also important to understand the pairwise relationships of different components of the framework. The understanding of gender differentiation in livestock production and disparities in climate change impact and response knowledge will lead to a more complete understanding of the influence of gender differentials in livestock production and disparities in climate change.

7. Conclusion

A goat-centered farming approach can help shift rural agrarian households and communities toward gender-inclusive climate change adaptation in agriculture to enhance food security and nutrition in sub-Saharan Africa. Gender inequality and climate change effects are compounding socioeconomic and environmental determinants that grossly compromise the stability of food production and food and nutrition security. Gender, climate change, agriculture, and food security are interrelated, and their dynamics are heterogeneous, complex, and rooted in social, economic, and institutional factors. The proposition in this chapter is that goat rearing can be a sustainable and holistic approach to addressing the triple challenges of gender inequality, climate change, and food and nutrition insecurity in rural communities of sub-Saharan Africa. This is grounded in the fact that goat rearing is an embedded integral component of a climate-smart livestock production strategy to increase rural agrarian resilience to climate change while improving food security and promoting gender equality. Apart from goats acting as an entry point for gender equality, they are a usable agro ecological, zone-specific, climate-resilient, thermotolerant animal species to sustain livestock production and enhance food and nutrition security. It is hypothesized that livestock production's susceptibility

to the vagaries of climate change can be mitigated by promoting adapted livestock species such as goats, which possess an ample degree of adaptation traits in terms of physiological, functional, and adaptive feeding behavior. This is based on the premise that climate change-induced variables continuously impinge on livestock productivity, which in most cases is the major cause of food and nutrition insecurity in rural agrarian households. Over the decades, goats have inherently acquired distinctive diverse physiological, morphological, and reproductive attributes that comparatively advance their survival and proliferation in unfavorable harsh heterogeneous agroecological niches of sub-Saharan Africa. In this regard, goats, due to their plethora of adaptive traits, emerge as a key facet in offsetting the destabilizing factors related to the uncertainties of climate change effects, in addition to goats being women's animals. However, there is a need to develop mechanisms and promote the viability of goat production through various operational and institutional strategies. The challenge is that most sub-Saharan African countries do not provide adequate policy for, nor do they prioritize, goat productivity in rural communities. In conclusion, there is still significant prejudice and ignorance about the critical socioeconomic and environmental role of goats in farming. Despite the overwhelming evidence that goat rearing is hugely beneficial for resource-poor rural communities in sub-Saharan Africa.

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