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Review article

Leveraging Agri-advocacy to promote animal genetic diversity for climate change mitigation: Kenya and Tanzania perspective

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ABSTRACT

The role that genetic diversity in animal genetic resources (AnGR) plays in mitigating the effects of climate change on the global protein supply is of the utmost significance. East Africa historically played a pivotal role in the dispersal of domesticated livestock species across the African continent. At present, it maintains a substantial contribution to worldwide biodiversity as a result of its reservoir of a diverse array of AnGR, characterized by genetic and species diversity. A considerable reduction in the genetic diversity of AnGR has been documented in numerous studies, giving rise to concerns regarding the sustainability of animal protein supply in the face of climate change. The objective of this article is to outline prospective roles that advocacy and management organizations specializing in AnGRs may undertake to aid in the conservation of AnGR genetic diversity in East Africa. Moreover, it provides a prospective framework and structure for advocacy that extends from the farmers, to the higher-level (regional farmers association). We believe that advocating for the promotion of genetic diversity at the regional level will have a significant impact at the national and further at global scale.

1. Introduction

Africa possesses outstanding natural resources that are conducive to the development of livestock, including vast expanses of land, abundant fodder, ample water supplies, and indigenous livestock breeds that exhibit adaptation to climate change [1]. The breeding management and preservation of genetic diversity of Animal Genetic Resources (AnGR) is a subject that carries significant social, economic, and environmental management consequences, albeit posing a formidable challenge in numerous African nations. AnGR encompasses a wide range of domestic livestock and poultry species, as well as their wild ancestors or closely related wild relatives whereas Animal Genetic Diversity (AnGD) refers to the genetic diversity present within species and within a single population. AnGR hold significant economic value for humans, particularly in terms of their contribution as a vital supply of animal proteins [2]. Indigenous breeds dominate African AnGR, but their performance is genetically inferior to that of commercial breeds. As a result, many

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advocates for improved livestock productivity including Government agencies as well as non-governmental organizations promote the adoption of commercial breeds over native counterparts. Indisputably, the rate of human population growth in Africa exceeds the capacity for animal protein production, it is therefore, imperative to implement focused measures aimed at enhancing sustainable livestock production, which includes adoption of commercial breeds but without forgetting preservation of the AnGD, which may be crucial in the future supple of animal proteins in the wake of climate change [3,4].

Climate change significantly contributes to the global decline of biodiversity. Biodiversity has three fundamental components: genetic diversity, species diversity, and ecosystem diversity. The reduction in biodiversity presents significant hazards to mankind, especially in the backdrop of continuous climate change. The rapid loss of biodiversity, particularly through the decline of genetic diversity, has garnered global attention and has been incorporated into various international accords, action plans, frameworks, and declarations. For example, matters related to biodiversity are addressed by Target 4 of the Global Biodiversity Framework (GDF [5]) and Sustainable Development Goal (SDG) 2.5, which specifically targets the genetic diversity of domesticated plants, animals, and their relatives. Other international agreements, including the European Union Biodiversity Strategy for 2030 and action plans, USAID Biodiversity policy acknowledge genetic diversity as a vital factor in guaranteeing food security [6,7]. One of the most concerning impacts of climate change is the increased frequency and severity of extreme environmental conditions, which pose a significant threat to the survival of many species. Therefore, one of the primary concerns regarding the improvement of AnGR in African livestock breeding pertains to the identification, development, and preservation of suitable genotypes/ecotypes/breeds that exhibit high level resilience towards the impacts of climate change. The impact of climate change on the global animal protein supply is of utmost importance and should not be underestimated [4]. Thus, it is crucial to recognize the importance of AnGD in the future sustainable supply of animal proteins.

Additionally, it is crucial to optimize breeding endeavors in order to facilitate "participatory" breeding approach, which is regarded as good approach by Newing et al. [8] i.e., the active involvement of farmers in the sustainable management of breeding activities, starting from the local level [9]. The successful execution of this process necessitates the effective coordination of operations across several levels, ranging from individual farms to the highest Agri-advocacy organization, following a hierarchical structure. East African community comprising of Kenya and Tanzania, and Uganda, Somali, DRC Congo, Burundi, Rwanda and South Sudan is primarily characterized by the prevalence of small-scale livestock farming. The primary focus of their breeding activities mostly revolves around the production of indigenous or crossbred livestock, sometimes with the intention of meeting subsistence needs or engaging in farmgate marketing endeavors, which involve selling products to neighbors or communities [2]. Usually, the farmers exhibit a deficiency in essential skills and information pertaining to enhancing productivity and gaining access to both local and international markets for their agricultural products. Therefore, governments hire livestock-extension personnel to provide extension services to livestock keepers regarding new management and breeding techniques in order to break even in their livestock enterprises. Farmers are commonly advised to enhance their livestock breeds by transitioning from indigenous varieties to exotic ones through cross-breeding. Insufficient emphasis is placed on the preservation of genetic diversity and the contribution of indigenous breeds towards attaining both national and global food security.

Therefore, the establishment of a robust Agri-advocacy system is crucial for effectively addressing the critical challenges of food security and the preservation of the vital AnGD. These endeavors can be aided by leveraging the knowledge and expertise gained from regions with well-developed agricultural sectors and established advising and extension services [1]. West European countries with a proven track record in livestock breeding management and robust breeding organizations should serve as a valuable model in this region. In Hungary, for example, attempts to preserve native breeds on the verge of extinction have been effectively executed by means of resilient advocacy systems [10,11]. Nordic countries have successfully implemented native domestic animal breeds by transforming their value from just genetic resources to cultural heritage [12]. Similarly, Poland has a well-established National Coordination Center for preservation of AnGR which works in coordination with other internally established bodies [13].

Furthermore, it is crucial to recognize the substantial capacity of East Africa countries in terms of its contribution to the global biodiversity especially with regards to the development of impacts of climate change resilient livestock breeds in the future.

We acknowledge that the high level of AnGD in East Africa particularly Kenya and Tanzania can be attributed to the native livestock breeds [14,15]. These breeds, however, face disadvantages in terms of their productive ability. Hence, we suggest a deliberate endeavor of advocacy aimed at supporting the breeding of these breeds. Affirmative action initiatives may encompass the creation of product-specific value chains that offer preferential pricing for products derived from indigenous breeds. Certain regions across the globe are adopting comparable approaches through the endorsement and implementation of pure organic farming practices. This paper, therefore, provides a summary of roles, significance, and potential of organized Agri-advocacy organizations in promoting the management of diversity of AnGR and breeding of climate change resilient breeds in the East African region, with Kenya and Tanzania being our case study countries. Our attention is directed towards Kenya and Tanzania due to their prominent economic status in East African, Africa and, on a global scale. It is posited that the achievements observed in Agri-advocacy for management of genetic diversity on AnGR in East Africa have the potential to exert a significant impact on analogous trends on a global scale. In addition, we provide a concise overview of the historical development of breeding management in the said two East Africa countries.

2. Material and method

The current study was conducted by a comprehensive literature evaluation, which entailed completing extensive searches on livestock breeding organizations in East African countries, with a particular focus on Kenya and Tanzania that were considered case studies to the research. The study encompassed the identification of breeding organizations and associations responsible for the management of AnGR in East African member states. The search includes all the stakeholders involved in the AnGR management

chain, they included: non-governmental organizations (NGOs), breeding organizations financed by donors, and community-based breeding initiatives Literature search followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocols [16] as illustrated in Fig. 1.The objective of this investigation was to ascertain the current framework for livestock breeding management and the conservation of genetic diversity of AnGR in East African community member states. We used farmers' association websites in order to ascertain the presence or past existence of an East African regional farmers' association responsible for coordinating advocacy efforts related to the management of AnGR in East Africa. The search encompassed a variety of sources, including published articles in Google scholar, farmers' associations, mainstream government agencies, and government policy documents. Additionally, it should be noted that a portion of the information included in this document is derived from the author's personal experience in the role of a livestock extension advisor. The search conducted in this study was not constrained by a certain time period, hence all sources of information were given equal weight and significance. A proposed framework and structure for the management of AnGR within-country up to the regional level of East Africa was developed.

3. Result and discussion

3.1. Importance of genetic diversity in the face of climate change

Climate change is an ongoing and escalating challenge, significantly affecting various aspects of human life, particularly the supply chain of animal-derived proteins. If not addressed effectively, its impacts are expected to worsen in the future. To mitigate the adverse effects of climate change on livestock, a range of strategies has been implemented. These include artificial methods, such as the creation of controlled microclimates, and natural approaches like nutritional interventions to reduce heat stress. Another key strategy is breeding climate-resilient livestock, often achieved by promoting the use of indigenous/native breeds or crossbreeding native breeds with commercial ones to enhance resilience. Among these methods, natural interventions—especially the breeding and preservation of climate-resilient populations—are widely regarded as more sustainable. A critical component of this approach is the preservation of genetic diversity, which plays a vital role in safeguarding the animal protein supply from the challenges posed by climate change. Genetic diversity supplies the essential substrate for evolution through natural selection [17]. Scientific research has demonstrated that genetic diversity within population enhances its potential to withstand diseases and pests [18,19]. Furthermore, genetically diverse populations provide a chance for within-breed selection to enhance the target traits [20]. Significantly, the considerable genetic diversity seen in domestic livestock animals is preserved in native breeds, rendering these breeds essential in the current and future endeavors to mitigate the impacts of climate change. For instance, studies e.g., Paim et al. [21], Shen et al. [22] and Saravanan et al. [23] inter alia have proved that indeed indigenous breeds have genetic potential to adapt to local environmental conditions such as heat stress, poor oxygen supply, prevalence of pests and diseases, poor terrain, poor quality and quantity pasture among other vagaries of nature. For further information on the significance of genetic diversity, please refer to Minter et al. [24] and Notter [25].

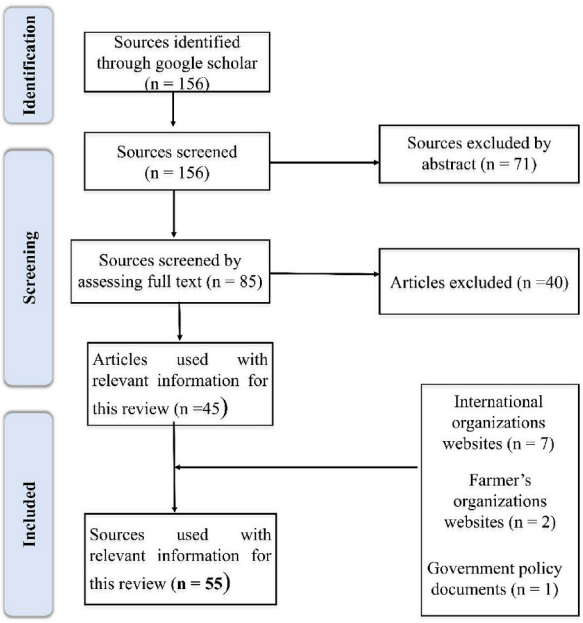

Fig. 1. A flowchart illustrating the literature review process, encompassing identification, screening, and included sources.

3.2. The historical development of livestock breeding organization in East Africa: A comparative study of Kenya and Tanzania

3.2.1. Kenya

Both in Kenya and Tanzania the initiation of livestock development efforts can be traced back to the 1920s, during the colonial period. These endeavors are primarily aimed at managing the prevalence of contagious livestock diseases, particularly Rinderpest and East Coast Fever (ECF) in cattle. The latter is transmitted by brown ticks (*Rhipicephalus appendiculatus*) [26]. Subsequently, a sequence of legislations was enacted to impose restrictions on the intermingling of livestock belonging to Africans and those owned by the British, particularly in the case of cattle, with the aim of mitigating the risk of African-owned animals transmitting diseases to the European exotic breeds [27].

The process of enhancing zebu cattle breeds owned by Africans began with the construction of Livestock Improvement Centers (LIC). By 1928, around 14 LICs had been formed with the aim of improving selected Zebu cattle. Sahiwal cattle were used for the purpose of enhancing Zebu by crossbreeding, owing to its recognized capacity for high milk production. Furthermore, the climatic conditions under which Sahiwal cattle were bred resembled those of Kenya, thus facilitating their adaptation to the local environment. The practice of artificial insemination (AI) was initially introduced in order to mitigate the transmission of infectious breeding diseases within European exotic cattle breeds. By the 1930s, AI had gained significant popularity among Europeans, with the scale of cattle insemination rivaling that of Russia [27]. However, it was not until the implementation of the Swynnerton plan in 1954 that Africans widely engaged in a cattle improvement program. In order to enhance dairy output in Africa, the government implemented subsidies for various input services like artificial insemination, production, animal health care, eco-parasite control, and the bulls' plan. However, the implementation of these subsidies was disrupted by the government's structural adjustment program [28].

Livestock performance recording was part of livestock development plans when the East African studbook (EASB) was established in 1920 followed by the East African milk recording Service (EAMRS) in 1969 under the sponsorship of the Royal Agricultural Society of East Africa [28]. Kenya studbook (KSB) was later established in 1963 following the collapse of the East African Community. Then in

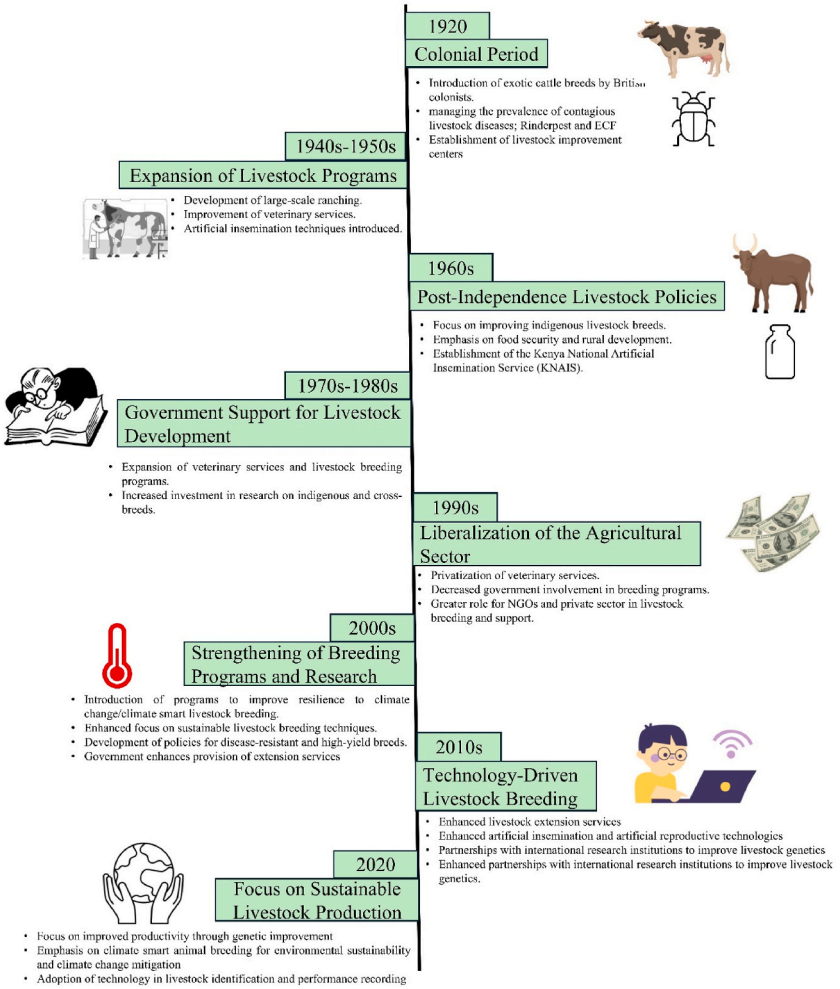

Fig. 2. A summary of historical perspective of livestock development in Kenya over time.

1970, the Kenya Milk Records (KMR) was established. Kenya studbook was maintained as a closed herd book to register animals as defined by various breed societies, whereas KMR was put under the Government of Kenya department of veterinary services. The main mandate of KMR was to carry out milk recording and butterfat testing for all farmers and share the report with the bulls purchasing committee and central artificial insemination station (currently referred to as Kenya Animal Genetics Resource Center-KAGRC). The latter would then use the information/report for selection of prospective bull-dams and sire to be used in contract mating schemes out of which young sires would be produced, superior ones purchased and used for semen production at the station [29,30]. After structural adjustment programs, the government suspended direct involvement in livestock husbandry. Subsequently, farmers who were running KSB established Dairy Recording Services of Kenya (DRSK) with support from the government to maintain dairy records on animals in Kenya.

Presently, the main body that manages livestock registration keeps pedigree records and registers progeny of the imported sires is Kenya Livestock Breeders Association (KLBA) formally the Kenya livestock breeders' organization (KLBO). The committee runs the studbook on behalf of other breed organizations. It was formed in 1994 after the farmers realized milk recording and livestock registration organizations had started undergoing financial constraints and poor coordination hence ineffective service delivery. To sustain animal registration and milk recording, farmers decided to group services of the two schemes under KLBC whose operations were fully funded by the farmers themselves with minimal support from the government [31]. Its main role was to coordinate and promote livestock breeding and improvement.

In 1901, John Ainsworth founded the Agricultural Society of Kenya (ASK), under the name East African Agricultural and Horticultural Society (EAA&HS), with the principal objective of promoting European settlement-based agricultural development. Mr. Ainsworth believed that society would be invaluable in promoting the market of Agricultural commodities [32]. ASK, as a member of the Royal Agricultural Society of the Commonwealth (RASC) is now regarded as the largest member in East Africa. Society has grown and spread branches across the country and provides an opportunity for players in Agriculture related activities to showcase their products and services to the public [33] in several parts of the country on an annual basis.

Having been established under the auspices of ASK, KLBA in collaboration with breed societies in the country organize annual livestock exhibitions, breeding stock sales, and trade fairs to promote Kenya's livestock industry nationally and internationally. Furthermore, KLBA also provides small-scale livestock farmer training through field days, residential and non-residential training, mostly in collaboration with the relevant government livestock extension service providers. Fig. 2 presents a summary of historical developments of livestock sector in Kenya.

3.2.2. *Tanzania*

According to the available literature, it has been documented that breeding activities in Tanzania were first established in the 1920s under the administration of the pre-colonial government. This early initiative involved conducting characterization work at the Mpwapwa Livestock Research Centre [34,35]. The breeding endeavors were then heightened throughout the 1960s with the establishment of expansive dairy farms, accomplished by directly importing *Bos taurus* breeds from temperate regions, predominantly Friesian and Ayrshire. During that period, many poultry breeds, including White Leghorns and Rhode Island Reds, were also introduced through importation. However, this particular technique encountered many obstacles, such as the insufficient adaptability of exotic breeds to tropical climates, resulting in their eventual discontinuation [36,37]. As a result, throughout the mid-1960s, there was a shift in breeding efforts towards the crossbreeding of *Bos taurus* bulls with local breeds, with the objective of enhancing the quality of the latter. Historical records demonstrate that the establishment of the National Artificial Insemination Centre in Arusha, which is today known by that name, occurred during this particular period. According to the authors, the primary objective of this center was to produce and distribute enhanced semen for the implementation of many crossbreeding initiatives within the country. Additional

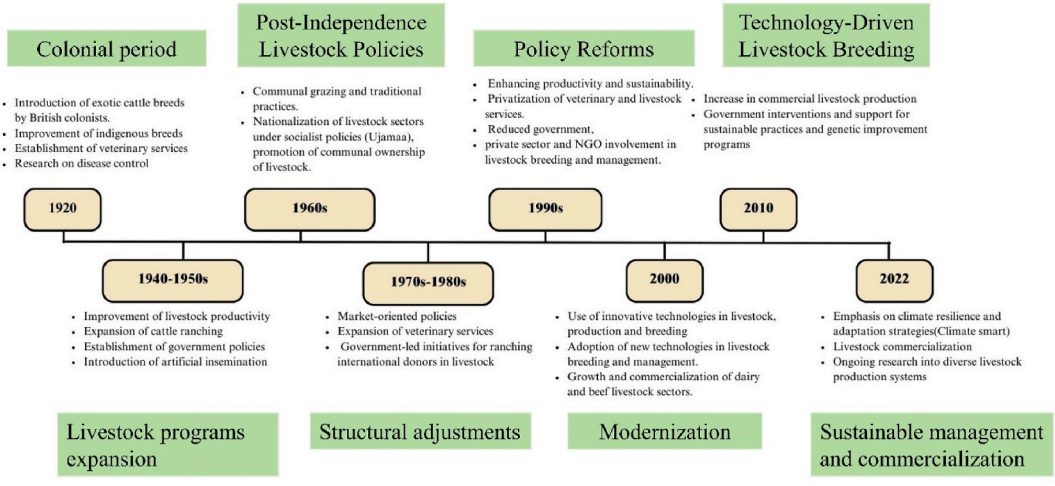

Fig. 3. A summary of historical perspective of livestock development in Tanzania over time.

initiatives were undertaken to enhance the availability of dairy heifers to small-scale dairy farmers by establishing Livestock Multiplication Units (LMUs) for the production of F1 heifers. The breeding farms primarily obtained indigenous Tanzania short horn Zebu (TSHZ) breeds from different regions of the country as initial stock for the purpose of crossbreeding. The resulting F1 heifers were then sold to smallholder dairy producers and non-governmental organizations at preferential prices as a form of encouragement. In contrast, throughout the 1970s, the establishment of two government entities, namely the National Poultry Company (NAPOCO) and Tanzania Animal Feed Company (TAFCO), took place with the purpose of supervising the advancement of the poultry sub-sector. The preceding organization was entrusted with the responsibility of supervising the functioning of breeding and hatchery facilities, as well as ensuring the production of all poultry meat and eggs throughout the nation. Conversely, the latter entity was assigned the duty of manufacturing animal feed products. However, during the 1990s, these agencies discontinued their operations, creating a space for the private sector to flourish and construct extensive chicken breeding farms within the nation. Fig. 3 provides an overview of the historical evolution of the livestock sector in Tanzania. There are considerable similarities in livestock development between Kenya and Tanzania, with the exception of the timing of their occurrence.

3.3. Prospective animal breeding organizations and their roles with regard to promoting management and diversity animal genetic resources in East Africa

In this context, breeding organization is regarded as defined by Herold et al. [38]. It is important to highlight that the precolonial evolution of the animal breeding organization landscape was primarily centered on the dairy sector. Again, the goal was to boost output, hence the promotion of commercial breed importation/use of commercial breeds to improve indigenous breeds. This phenomenon persisted for decades until scientists discovered that several imported breeds and/or cross-breeds performed badly in tropical conditions when compared to local varieties [15].

The subsequent discussion on the structure of animal breeding organizations is based on the perspective of the Kenyan system, which is subsequently enlarged to encompass regional breeders' association. It is anticipated that every member state in East Africa will implement a comparable approach in order to collectively pursue the objective of achieving sustainable breeding management, preserving genetic diversity, and conserving climate change adapted AnGR.

Animal breeding organizations contribute to the promotion and improvement of AnGR through their involvement in Agri-advocacy efforts. Agri-advocacy of animal breeding activities, ranging from the producer to the consumer is a complex activity, it requires proper multi-disciplinary coordination of activities and services of multidisciplinary players to eventually produce a robust breeding system and advocacy system. Below are descriptions of within-country key players in Agri-advocacy for the promotion and conservation of AnGR diversity.

3.4. The public sector (national governments)

The government plays a significant role as a key stakeholder in the animal breeding process. The government is widely recognized as the primary political entity representing the interests of the animal breeding community. In this scenario, the government assumes a significant role in the promotion of breeding and protection of Animal AnGR by establishing favorable political, economic, and social conditions that facilitate the effective functioning of Agri-advocacy organizations. Policy formulation and implementation is a significant role undertaken by the governments. In addition, there are further tasks associated with the regulation of quality of breeding materials, as well as the establishment and support provided to public institutions engaged in the advancement and facilitation of animal breeding activities. In Kenya, some organizations involved in livestock management and breeding include the Livestock Recording Center (LRC), Government Breeding Farms, and Bulls' Stations such as the Kenya Animal Genetic Resource Center (KARGC) and Livestock Genetic Societies (LGS) like the Agricultural Development Corporation (ADC) farms. In Tanzania, similar organizations include the Tanzania Dairy Board (TDB), Tropical Pesticides Research Institute (TPRI), and Tanzania Food and Drugs Authority (TFDA) according to Tanzania National livestock policy [39]. Besides, the government is responsible for research and development, and thus, institutions like Kenya Livestock Research Organizations, and public universities were established (in Kenya). Moreover, animal husbandry training (and extension services) for farmers and producers is also part of the functions of the government.

3.5. National livestock breeders association (NLBA)

The KLBA represents Kenyan livestock breeders at the national level. Although it is uncertain whether Tanzania has a similar national breeders' association, the Tanzania Poultry Breeders Association (TPBA; https://www.tpba.or.tz) represents the poultry sub-sector. The NLBA represents breeding societies and operates as a national lobbying body for breeders. This organization's primary functions are to provide extension services to livestock breeders, to facilitate livestock registration and record keeping through the Studbook, to coordinate performance recording, and to arrange national livestock exhibitions, shows, and trade fairs. They advocate for farm subsidies and tax incentives to help farmers cut production costs. In line with breeding and conservation of climate change adapted breeds, NLBA should collaborate closely with research institutes to investigate a balanced approach to improved productivity and genetic diversity maintenance.

All of the NLBA's functions are carried out through coordination and collaboration with species- or breed-specific societies. In Kenya at present, KLBA has registered at least thirty (cattle = 17, goats = 5, sheep = 6, and pigs = 2) livestock breeds for all farmers who came together through breed societies to improve their breeds (KLBA, https://klba.or.ke).

3.6. Species-breed specific societies

These organizations offer a range of services including financial aid or credit facilities, extension services, input supplies, and marketing outlets for livestock production. In addition, they provide backing for the augmentation of output and productivity, as well as the facilitation of processing, marketing, and credit mobilization. The active engagement of communities and their respective organizations is vital to guarantee the achievement of desired outcomes in participatory advocacy and implementation efforts. Some breed societies found in Kenya include Fleckvieh Genetics East Africa Ltd, Ayrshire Cattle Breeders Society of Kenya, Holstein Friesian Cattle Breeders Society of Kenya, Jersey Cattle Breeders Society of Kenya, Sahiwal Cattle Breeders Society of Kenya, Galla Goat Breeders Society of Kenya, Dairy Goats Association of Kenya, and Dorper Sheep Association of Kenya, among others. Similarly, in Tanzania, they include Tanzania Milk Processors Association (TAMPA), Southern Eastern Zone Goat Development Network (SEGODEN), and Tanzania Milk Producers Development Association (TAMPRODA), among others Tanzania National livestock policy [39]. It is important to acknowledge that a significant proportion of breed-specific associations primarily focus on commercial breeds, which have experienced a reduction in genetic diversity due to intense selection pressures. Indigenous breeds are often overlooked in contemporary breeding practices, necessitating intentional efforts to prioritize and enhance the breeding management of these breeds. It is suggested that national governments or international organizations should consider providing incentives for the implementation of breeding management strategies for indigenous livestock breeds.

3.7. Development partners

Development Partners are mainly international organizations and organizations that have an interest in animal breeding in the country. They allocate resources towards the advancement of the livestock industry. They play a pivotal role in providing support for various government initiatives aimed at addressing the prevailing challenges in livestock development. They offer support in the form of financial resources and technical expertise for various interventions undertaken in programs aimed at achieving predetermined objectives and driving the country's economy towards sustainable growth [40,41]. In most cases, they support animal breeding activities through government agencies and grants to breeding groups. They include Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ [42]), International Livestock Research Institute (ILRI [43]), International Fund for Agricultural Development (IFAD [44]) and Food and Agriculture Organization (FAO [45]) inter alia. The region of East Africa has not yet fully taken advantage of this support to actively promote the protection of landrace genetic resources, which possess potential utility in the future, particularly in light of the challenges posed by climate change. While the current focus of the nation lies on achieving immediate goals like food security and poverty alleviation, it is imperative to also consider the aspect of sustainability for the future.

3.8. Private sector

The private sector consists of commercial institutions that are motivated by the pursuit of profit. The majority of their operations are specialized commercial activity within specific nodes of the livestock product value chain. They include input suppliers, traders, processors, transporters, and several other stakeholders. The active involvement of the corporate sector in agricultural advocacy, specifically in the management and promotion of diversity in animal genetic resources (AnGR), is a promising avenue for addressing the challenges encountered in the livestock sector. By providing practical suggestions and solutions, private sector participation can contribute to the effective resolution of these challenges. An example of private sector players in Kenya are genetic importer's whole main role is to introduce foreign genes of commercial livestock breeds. They import semen for breeds like Holstein Friesian cattle, Dairy goats e.g Toggenburg [46], Dorper sheep [47]. Importers of genetic materials and service providers mainly import and distribute semen and embryos for improved breeding in Kenya. Moreover, they also play a crucial role in liquid nitrogen distribution. An example of importers includes American Breeding Services (ABS), Worldwide Sire (WWS) limited and Semex, etc.

3.9. Livestock breeders/farmers

These are the primary stakeholders in the improvement and management of Animal Genetic Resources. Various entities can serve as farmers, including individuals operating on a small or big scale, community-based organizations (CBOs), self-help groups, and cooperative societies. These farmers have the potential to serve as both multipliers and eventual users of the breed. If the participatory genetic improvement and management of AnGR plan development incorporates the farmers, the resulting outcomes would likely be broadly embraced and implemented collectively, hence enhancing sustainability. As multipliers, they offer high-quality breeding stock to their fellow farmers, while also facilitating peer extension services in the form of farmer-to-farmer training. They give feedback to the breed societies on what aspects of the trait should be improved to ensure sustainability.

3.10. Other institutions

Various public and private institutions, both directly and indirectly, contribute to the genetic management of Animal Genetic Resources. These include professional organizations, entities responsible for quality assurance, regulatory agencies, and several other stakeholders.

3.11. Potential of utilizing animal breeding associations to strengthen agri-advocacy for climate change adapted AnGR management in East Africa

Multiple studies e.g. Refs. [48–50], have indicated that East African countries possess a rich diversity of AnGR. However, it is observed that the abundance of AnGR is diminishing, maybe as a result of uncontrolled crossbreeding practices and inadequate genetic management of these resources. The effective promotion of genetic diversity preservation in AnGR and the development of climate change-adapted breeds necessitate the adoption of a multidisciplinary strategy that incorporates both vertical and horizontal relationships (Fig. 4). To enhance the effectiveness and efficiency of vertical and horizontal coordination, it is imperative for national governments to prioritize the harmonization and evaluation of appropriate legal instruments pertaining to the livestock sector, while entrusting the responsibility of actual coordination to relevant stakeholders. It is important to acknowledge that a potential obstacle to the preservation of genetic diversity lies in breeding systems that prioritize profit. The implementation of this system has resulted in the need for intensive selection in numerous breeds, thus leading to a notable decrease in diversity levels, particularly within the dairy subsector [51]. Additionally, this phenomenon is observed in the majority of commercial breeds across various species e.g., layer poultry [52]. Nevertheless, indigenous breeds are believed to have preserved considerable levels of diversity [53], despite their low productivity genetic potential. As stated before, almost all species- or breed-specific associations focus on commercial breeds since indigenous counterparts are not profitable. Hence, the sustainability of maintaining genetic diversity through the promotion of indigenous breeds will be compromised if entrusted solely to private investors. It is recommended that the government intervene by providing incentives aimed at promoting the development and genetic improvement of indigenous breeds, thereby facilitating the sustainable management of genetic variety. Moreover, in order to effectively achieve sustainable poverty alleviation and food security, it is advisable for development partners to prioritize the allocation of their resources towards the genetic enhancement of indigenous breeds. This is primarily due to the fact that native breeds require lower management costs compared to commercial breeds, and many of them have already integrated into rural communities where commercial breeds are unable to thrive.

The establishment of the African Animal Breeding Network (AABNET) has provided a significant boost to the endeavors aimed at improving the management of genetic resources in Africa. AABNET functions as a network comprising professionals in the field of animal breeding, and its primary objective is to provide technical assistance to animal breeding organizations across the African continent. For more information about AABNET, please visit their website at [53]. The primary objective of this initiative is "to facilitate the advancement and widespread adoption of enhanced animal genetics and comprehensive genetic improvement strategies within the African context." Another potential boost for the management of animal genetic resources in Africa involves the implementation of two initiatives, namely the Peste des Petits Ruminants Pan-African Program and the Resilient African Feed and Fodder Systems (RAFF) programs, facilitated by the African Union's Intra-African Bureau for animal resources [54]. Both initiatives are financed and executed within the framework of the African Union and are expected to have a substantial influence on the AnGR in various parts of Africa. If the national and regional associations were to seize the opportunity, the sustainable management of AnGR may be realized.

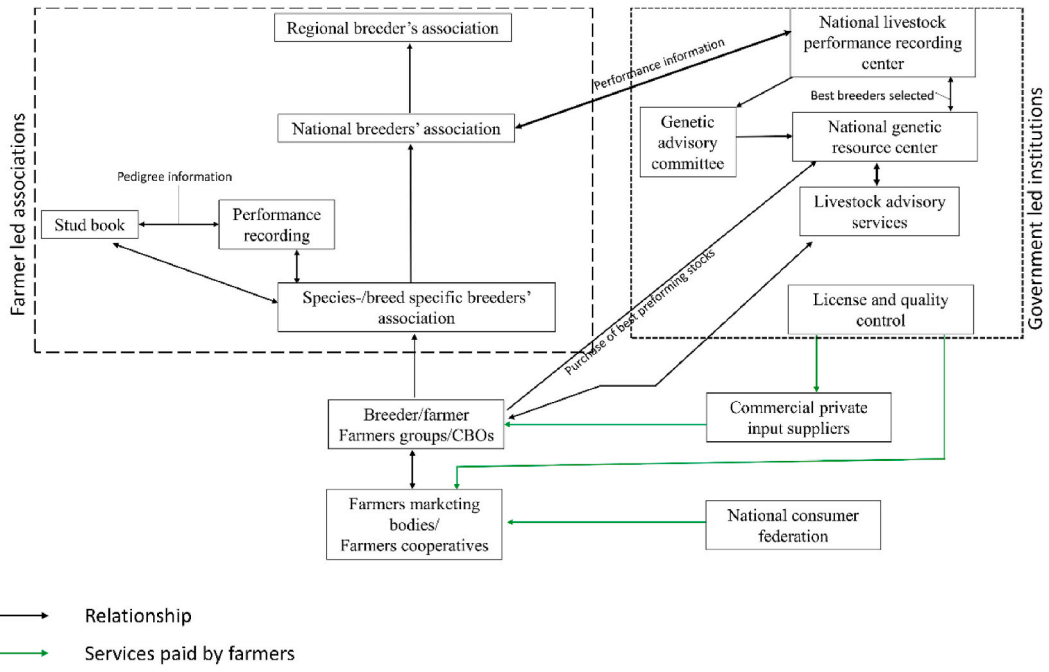

Fig. 4. Prospective schematic presentation of institutional and organizational framework of animal breeding in East Africa.

4. Conclusion

In summary, the conceptual framework emphasizes how government-led organizations, farmer-led groups, and animal breeding service providers are all intertwined. Breeder-led organizations that collaborate to manage pedigree data and performance are essential to preserving breed quality. Examples of these organizations include national breeders' associations, breeder groups, and species-specific breeders' associations. The national livestock performance recording center and genetic advisory committees, two government-run organizations that offer crucial regulatory monitoring, genetic resource management, and consulting services, receive performance data from these associations. Furthermore, in order to supply the essential inputs and maintain standards for product quality, service providers—such as national consumer federations and commercial sector input suppliers—play a crucial role and farmers meet the costs of these services. By pooling resources and knowledge, this integrated network makes sure that breeding procedures are sustainable, well-regulated, and constantly improved.

CRediT authorship contribution statement

George Wanjala: Writing – original draft, Conceptualization. **Lenox Omondi Pius:** Writing – original draft, Conceptualization. **Péter Strausz:** Writing – review & editing, Methodology. **Szilvia Kusza:** Writing – review & editing, Supervision, Formal analysis, Conceptualization.

Data availability statement

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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5. GLOSSARY

AnGR	Animal genetic resources
AABNET	African Animal Breeding Network
CBOs	community-based organizations
RAFF	Resilient African Feed and Fodder Systems
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
ILRI	International Livestock Research Institute
IFAD	International Fund for Agricultural Development
FAO	Food and Agriculture Organization
NGOs	non-governmental organizations
TAMPA	Tanzania Milk Processors Association
SEGODEN	Southern Eastern Zone Goat Development Network
TAMPRODA	Tanzania Milk Producers Development Association
LIC	Livestock Improvement Centers
ECF	East Coast Fever
KAGRC	Kenya Animal Genetics Resource Center
AI	artificial insemination
EASB	East African studbook
EAMRS	East African milk recording Service
KSB	Kenya studbook
KMR	Kenya Milk Records
DRSK	Dairy Recording Services of Kenya
KLBA	Kenya Livestock Breeders Association
KLBO	Kenya livestock breeders' organization

ASK	Agricultural Society of Kenya
EAA&HS	East African Agricultural and Horticultural Society
LMUs	Livestock Multiplication Units
TSHZ	Tanzania short horn Zebu
NAPOCO	National Poultry Company
TAFCO	Tanzania Animal Feed Company
LRC	Livestock Recording Center
KARGC	Kenya Animal Genetic Resource Center
LGS	Livestock Genetic Societies
ADC	Agricultural Development Corporation
TDB	Tanzania Dairy Board
TPRI	Tropical Pesticides Research Institute
TFDA	Tanzania Food and Drugs Authority
NLBA	National Livestock Breeders Association
TPBA	Tanzania Poultry Breeders Association

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