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Systematic Review

Current and Future Challenges and Opportunities for Livestock Farming in West Africa: Perspectives from the Case of Senegal

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Abstract: Livestock farming is a livelihood activity and is critically important for the food and nutritional security of the majority of the population in West African countries, including Senegal. Nevertheless, livestock farming operates far below the optimum production potential, mainly due to demographical, biophysical, economic, environmental, and sociopolitical challenges. To address these issues, we conducted this review with an overall objective of characterizing different livestock farming systems and to identify challenges and opportunities to improve livestock production in West Africa through the broader perspectives from the case of Senegal. Pastoral, agropastoral, and off-land systems are the three major livestock production systems in this region, which are unique in terms of agroclimatology and degree of intensification and integration. The major challenges identified in livestock farming systems are lack of pasture and quality feed, scarcity of water resources, climate change, undeveloped breeding and management of livestock, poor marketing and trade, and socioeconomic constraints. Moreover, we contribute to the literature on crop-livestock farming in Senegal and West Africa by proposing plausible interventions to improve the productivity of the farming system to improve food and nutritional security. Concentrated efforts must be taken in co-designing effective management interventions for sustainable intensification of livestock sector in the region, considering site-specific approaches.

Keywords: agroclimatology; agropastoral system; food security; climate change; intensification; pastoralism

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1. Introduction

The West African region consists of 16 countries, namely, Benin, Burkina Faso, Cape Verde, The Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, and Togo, and an overseas territory of Saint Helena. According to the United Nations, West Africa also comes under the greater region of Sub-Saharan Africa, with an estimated human population of around 400 million [1]. The total population of West Africa is projected to reach more than 800 million by 2050 and poses a greater challenge for the food and nutritional security of the region [2]. Livestock are important assets and are an integral part of the African agriculture and farming system [3,4]. Livestock farming involves at least 60 million people while accounting for a large

portion (8–15%) of gross domestic product (GDP) for many of the West African countries' economies [5]. In the same region, the share of livestock to agricultural GDP is around 44%, and it could reach up to 50% if the value of labor (i.e., animal traction) and manure are accounted into the livestock products [6,7]. Furthermore, livestock production accounts for 34% of the revenues of rural communities; therefore, it is one of the key determinants of food and nutritional security in this region [8]. West Africa has the major livestock population and genetic diversity in Sub-Saharan Africa. The region consists of 25% of cattle, 33% of sheep, 40% of goats, and 20% of camels of the greater Sub-Saharan Africa; however, other livestock species are also grown in the regions in smaller proportions, such as pigs, poultry birds, camelids, horses, and donkeys [9]. A recent estimate of the Food and Agriculture Organization (FAO) shows that West Africa is home to a livestock population of roughly 103 million tropical livestock units (TLUs), with an increasing trend in the animal population [2]. The contribution of this sector to the livelihood of the people in the region includes milk, meat, eggs, manure, traction, emergency cash reserve, and other sociocultural functions [10,11]. However, a recent projection has shown that demand for red meat will increase in the region to 6–7 million metric tons (MT) per year by 2030, surpassing the supply by on average around 1.7 million MT per year [12]. This highlights the importance of increasing local production through appropriate management interventions, policies, and investments.

In summary, many constraints currently hinder tapping the production potential of livestock farming in the West African region, including Senegal. Meanwhile, there is a need for a comprehensive review of the characteristics of different livestock farming systems in the region, and to present their challenges and opportunities to exploit the production potential to ensure food security. Although an extensive body of literature and project reports are available on the livestock systems in West Africa, geographical, demographic, and socioeconomic conditions are largely different in each of the countries. Moreover, each country will have different levels of vulnerability and resilience to global change factors. However, Senegal is a good representative of agroclimatology of West Africa, and is thus an appropriate case for crop–livestock farming systems in the region. To this end, the objectives of this review were to (1) present the characteristics of different livestock farming systems in Senegal, (2) identify the challenges and opportunities to improve livestock production in Senegal and West Africa, and (3) provide recommendations to develop the livestock sector and ensure food security in the region.

2. Methodology

This review was conducted as a case study in Senegal within the largest context of Western Africa following the PRISMA statement [13]. An exhaustive literature search was conducted in Google Scholar and Scopus using the keywords "livestock farming", "livestock production", "Senegal", "West Africa", "challenges", "climate change", and "food security". Boolean search commands, namely, AND, OR, and NOT, were used to combine relevant information and avoid duplications. Finally, the search results were moved through identification, screening, eligibility, and inclusion steps according to the PRISMA model for systematic reviews (Figure 1).

Identification/indexing is presented at the top of Figure 1 and involves the search for relevant sources and terms. Next, during the screening process, all duplicated articles were removed. In addition, those articles that do not provide an answer to the research questions (i.e., the objectives of the paper) were removed. Finally, the articles with restricted access were excluded. After reviewing the full text of all remaining articles at the screening stage, our criteria based on the research topic were used to determine articles that should be further excluded. From this point, the remaining articles are considered for the systematic review [13]. The population for this systematic review was major livestock species and livestock farming systems in Senegal; intervention was the challenges faced by the livestock farming systems, while key interventions were the proposed outcome.

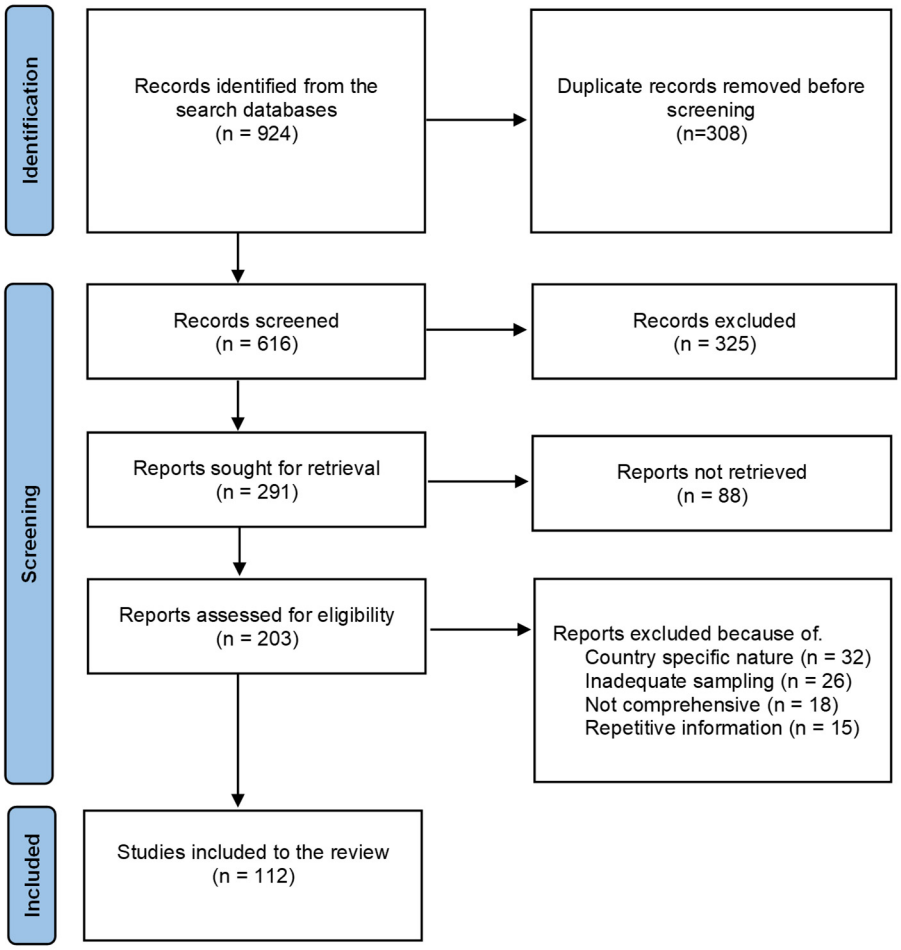

Figure 1. Schematic diagram of the systematic review process.

Only peer-reviewed manuscripts published in the indexed journals and reports by reputed government and non-government organizations were considered to ensure the quality of data and information sources. In addition, a cross-referencing approach was used to collect the required information from the papers cited in the list of references. For example, when an included research article presented a very important finding which is secondary in nature, the original article was found through cross-referencing. Studies with inadequate sampling or repetitive information or that were area-specific or non-comprehensive were not considered for this review. Finally, a total of 112 studies were used to extract the data and information for this comprehensive review.

3. Results and Discussion

3.1. Agroclimatological Conditions in West Africa

Bioclimatic conditions play an important role in deciding the characteristics of livestock farming systems in West Africa [14]. According to the climate and vegetation, the bioclimatic zones of West Africa could be categorized into four zones: (1) the Saharan (dessert), (2) the Sahelian (arid), (3) the Sudanian (semiarid), and (4) the Guinean (sub-humid/humid) [15,16]. The Saharan zone has extremely low rainfall (<500 mm/year), while the Sahelian and Sudanian zones have a unimodal rainfall pattern occurring as a single rainy season (500–1000 mm/year) with a duration of 3 to 4 months. Rainfall in the humid (Guinean) zone ranges between 1000–1500 mm/year, and has both uni- and bimodal patterns depending on the location [17]. For example, the bimodal rainfall pattern (i.e., both a short and a long rainy season) was observed in coastal areas located near the

Gulf of Guinea, while northern inland regions of the Guinean zone experience unimodal rainfall patterns [16].

3.2. Livestock Farming in West Africa

Livestock farming systems in West Africa can be broadly classified into three systems: (i) pastoral system, (ii) agropastoral system, and (iii) off-land system, depending on the management and availability of feed and water resources [8,17]. The Fula/Fulani/Fulbe/Peul people are the major ethnic group involved in livestock farming in West Africa, while the Wolof people are the ethnic majority (~43%) in Senegal [18,19].

***(i) Pastoral system*:** Primarily practiced in the arid and semiarid zones where the livestock production entirely depends on natural pasture, and the animals are grazed in uncultivated lands. This system involves extensive management of moving herbivorous livestock where they are managed as mixed or individual herds of different animal species [6,8]. In addition, around 80% of pastoralists in this region have an income below the poverty line, making them more vulnerable to environmental and socioeconomic challenges [12].

Although there may be disagreements, pastoralism is often considered as the most appropriate animal production system in dryland agriculture since deliberately moving herds is the best way to exploit spatiotemporally variable forage, fodder, and water resources. Therefore, this system represents an important livelihood strategy and a way of life in this part of the world [20–23].

The pastoral system can be further divided into two types, depending on the mobility of the system: nomadic and transhumant pastoralism [17]. In nomadic pastoralism, herders frequently move the livestock in search of pasture and water without permanent shelter or cropland. Nomadic pastoralism exists in the areas with lower and irregular rainfall, including the northern Sahel and parts of Mali and Niger closer to the Sahara [2]. Meanwhile, herds are moved seasonally within well-defined territories in transhumant pastoralism. Generally, at the beginning of the dry season, herds are moved from the Sahelian zone as a result of pasture and water scarcity to the sub-humid zone, where the forage and water will be available, and then returned to their original places with the onset of the rainy season [17,24]. The pasture available in the Sahelian zone during the rainy season will be high in quality. Meanwhile, animals such as lactating cows and those unable to walk for distances are usually kept at home. Livestock are commonly corralled during the nighttime in the grazing fields to facilitate manure collection in the lands that will be later used for crop cultivation by the farmers in the sub-humid zone, reflecting a social contract between herders and farmers [11,25,26]. However, the increasing movement of transhumant pastoralists towards the southern sub-humid zone is causing competition for grazing resources and conflicts between herders and crop growers [2].

The transhumant pastoral system is the dominant livestock production system among the pastoral systems in West Africa. It is responsible for the supply of about 65 percent of beef, 40 percent of mutton, and 70 percent of milk in this region [22]. In general, transhumant pastoralism is influenced by climate variability (e.g., drought and high temperatures), availability of pasture, animal diseases, changes in demography and land use, and social relations and networks with the host communities. Especially with the population growth, expansion of crop cultivation into grazing lands, and increasing frequencies of drought events, herders perform long-distance transhumance to the sub-humid zones [18,27,28]. Meanwhile, it was reported that some transhumant pastoralists were involved in small-scale agriculture, especially in some parts of the Sahel when the rainfall is more than 200 mm/year. Moreover, many young pastoralists are seasonally involved in small-scale trade and commerce in urban areas and coastal countries as opportunities to diversify their income [29].

***(ii) Agropastoral system*:** An agropastoral system is a mixed farming system where crops and livestock are integrated at different scales by settled farmers. The mixed crop–livestock system provides food security for millions of people in West Africa and other

developing countries [30]. Animals may graze in uncultivated lands, crop residues in cultivated lands, fodder crops, and be fed with agricultural/agroindustry byproducts and purchased feeds [8]. The agropastoral system is very common in sub-humid savannah zones of West Africa, where farmers are rearing animals for manure, traction, and as a cash reserve [10]. Moreover, population growth and increasing occurrences of extreme droughts have also led to the adoption of agropastoralism in this region [31]. Meantime, some agropastoralists were observed to practice long-distance transhumance at a few locations.

Several crops (cereals, legumes, plantains, root and tubers, fruit trees, and vegetables) are integrated with livestock in this system, such as pearl millet–cowpea–livestock, pearl millet–groundnut–livestock, sorghum–maize–cowpea–livestock, maize–sorghum–livestock, rice–groundnut–livestock, rice–livestock, vegetables–rice–livestock, cotton–maize–sorghum–livestock, rice–cassava–maize–livestock, cassava–maize–yam–livestock, yam–cassava–livestock, cocoa–plantain–cassava–livestock, and coconut–oil palm–fruits– livestock [17]. Most of these systems are rainfed; however, irrigated systems can also be found near the flood plains and deltas of major rivers such as the Senegal River, the Niger River, and the Sokoto River [2].

Among these systems, the pearl millet–cowpea–livestock is widely practiced across West Africa, where pearl millet is grown alone or intercropped with cowpea (Figure 2). In fact, pearl millet was the earliest domesticated crop, and has led to the evolution of the agropastoral system in West Africa [32]. Although most of the crops are annuals and are grown during the rainy seasons, perennial crops such as cocoa, coconut, oil palm, and fruit trees are integrated to reasonable extents, especially under agroforestry systems. Crop residues, straw, hay, leguminous fodders, cottonseed cake, peels of yams/cassava, cocoa pods, and agroindustry byproducts (e.g., bran, poonac) are used to feed the animals [17]. It is also important to highlight that the proportion of livestock and crop integration widely varies across the agropastoralists in this region, and the clear distinction between pastoral and agropastoral systems is becoming unclear because of the growing involvement of pastoralists with crop cultivation [6]. Kamuanga et al. (2008) argued that both the pastoral and agropastoral systems are responsible for producing 80% of livestock goods in West Africa [8]. Moreover, pastoralists have shown greater adaptability to changing circumstances by pursuing a combination of extensification and intensification strategies [33].

(iii) Off-land system: This is generally landless livestock farming where the animals are managed under stall-feeding, especially in the urban and peri-urban settings [8,17]. In addition, the economic, societal, and environmental costs of production are largely higher for the off-land systems than the agropastoral and pastoral systems. However, stall-feeding is not only limited to landless systems, because sometimes grazing animals are receiving supplementary feed, especially during lactation and fattening [34]. Livestock in the off-land system is fed with cultivated fodder, concentrates, cereals, straw, hay, unrefined agroindustrial byproducts, pulp of *Parkia biglobosa,* and cut-and-carry fodders with the aim of fattening and milking [9,35]. This system can be intensive or semi-intensive and promoted to improve food and nutritional security and to diversify income generation for urban residents. Furthermore, the livestock feed ration used in the off-land systems may represent the nearby agropastoral arrangement and animal breeds. Poultry, pig, and small ruminants are the prominent components of this system, and it demonstrates a growing trend in parallel to the urbanization in this region [36].

The demand for livestock trade is increasing especially in coastal countries such as Nigeria, Ghana, and Côte d'Ivoire [18]. Moreover, the demand for meat and milk is projected to increase with the rise of income per capita in many West African countries in which rich and medium-revenue consumers turn towards animal-based protein-rich food [6]. However, the livestock production and supply are unable to meet the demand regardless of the existing production potential in this region [37]. Hence, substantial quantities of meat and milk are still imported from countries outside of Africa at the expense of foreign exchange [8].

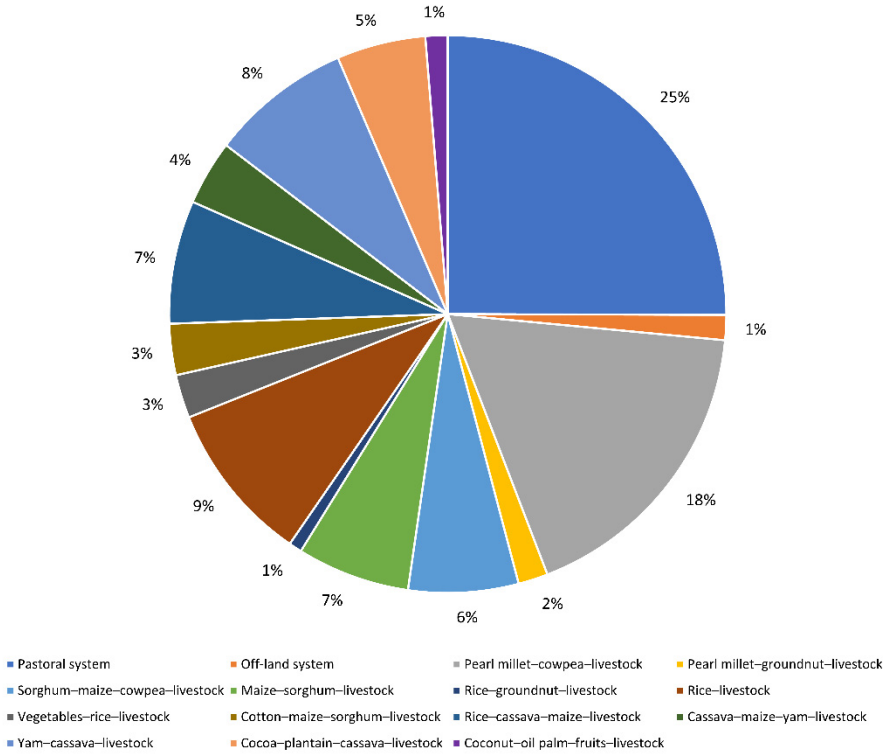

Figure 2. Percentage of the land area of different livestock farming systems in West Africa ([17]).

3.3. Livestock Farming in Senegal

Livestock farming is the livelihood of 60 percent of Senegal's population and offers about 30 percent contribution to the agricultural GDP, and is heterogeneously ecologically embedded with local food systems [2]. The land-use map of Senegal portrays the pastoral system (i.e., grassland) in northern Senegal and the agropastoral system (i.e., cultivated land) dominating in the east and south (Figure 3). The intensive off-land system is in the urban areas closer to its capital Dakar [38]. The existence of these systems is based on the climatic gradient from north to south, with annual rainfall ranging from 300 mm to 1300 mm [39].

Transhumant pastoralism is mainly internal within the country, and animals are generally moved towards the Groundnut Basin and Oriental Senegal [2,17]. As a result of population growth, agricultural encroachment, political violence, and instability, a majority of Fulani pastoralists moved from the Senegal River Valley to the south of the Ferlo region [27]. In the 1950s, boreholes were established by the French as water sources, which facilitated pastoralists to extensify grazing pressure and specialize their production [27,40]. Nevertheless, with annual rainfall less than 500 mm constricted within two months, herders have no choice but to move in search of pastures [40,41]. Turner and Schlecht (2019) identified this mobility as a latitudinal transhumance that uses more than 100 routes with the maximum radius of annual travel movements ranging from 5 to 200 km [23]. These routes consist of interconnected networks of transhumant corridors, encampment sites, and water sources to accommodate the seasonal mobility of pastoralists and livestock herds from north to south [28,42]. According to Rass (2006), the pastoral system produces 24 percent of beef, 11 percent of goat meat, and 13 percent of sheep meat in terms of Senegal's total national production [20].

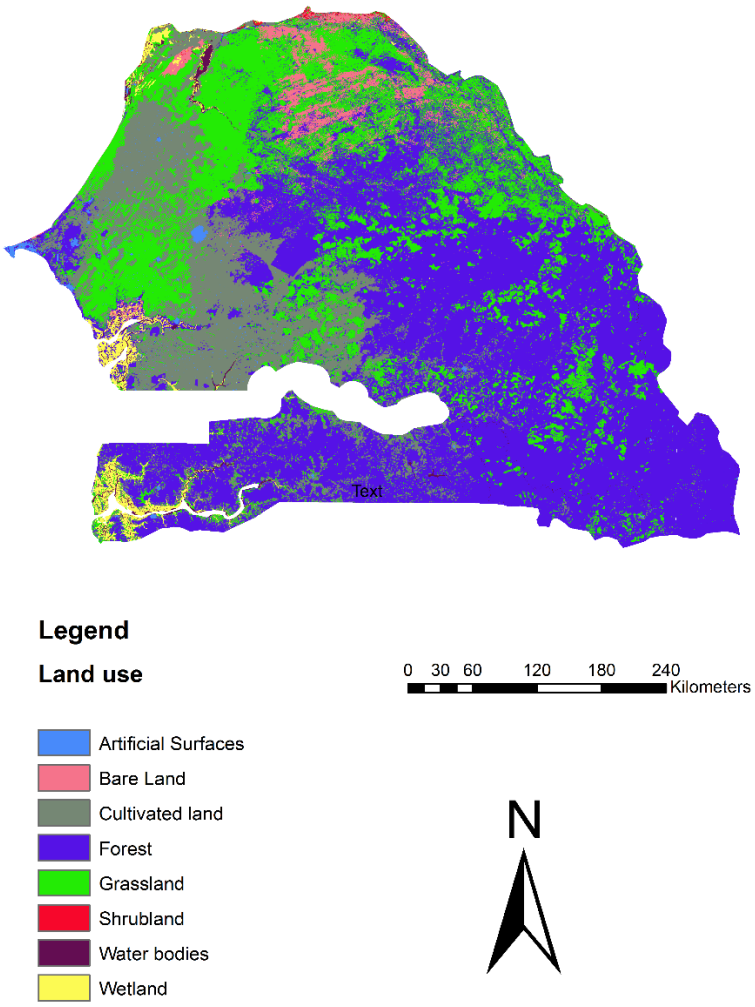

Figure 3. Land-use map of Senegal at 30-meter resolution.

There are two major agropastoral systems in Senegal, namely, pearl millet–groundnut–livestock system in the northern region and rice–groundnut–livestock system in a region called Basin Arachidier, or peanut or groundnut-producing basin [17]. The reason for the existence of these systems is that the pearl millet and groundnut are the major crops, and rice is the staple crop of the Senegalese [43,44]. The agropastoral system consists of 67% of the cattle population and 62% of the small ruminants, and this livestock provides 10–50% of income for each household [2]. The majority of the agropastoral system is rainfed; however, the country has around 400,000 ha of agricultural land under irrigation, mostly found along the Senegal River, where 93 percent of the total extracted water is used for agriculture [43,45]. Pastoralists and agropastoralists were also observed to involve non-farming activities, such as livestock trade, as means of diversifying their livelihood activities [41].

The off-land system consists of the modern poultry and swine industry in the urban and peri-urban areas of Senegal, where they are managed in close contracts with western companies that offer feed formulas, concentrates, chicks, breeding facilities, extension services, veterinary care, and marketing ventures [8]. Cereal grains, brans, and kitchen waste are the major ingredients of animal feed in this system. The adaptation of new technologies among livestock keepers was evident due to the higher literacy rate in the urban areas [35]. Around 65 percent of the national requirement of poultry meat and eggs are produced around the greater Dakar region, while land availability and environmental pollution are the pressing issues in this region [46].

The recent count of livestock species in Senegal is presented in Figure 4. Accordingly, the population of small ruminants such as sheep and goats is larger than cattle. This is in agreement with Fernández-Rivera et al. (2004) [17], where herders began to raise more small ruminants following the prolonged drought period of 1969–1974. These small animals are generally more drought-resilient relative to cattle and are more prolific in rebuilding the flock quickly. The population of swine is smaller, while almost all livestock species show an increasing trend in their population. Chicken dominates among the poultry species and shows a sharp increase in urban and peri-urban settings (Figure 4).

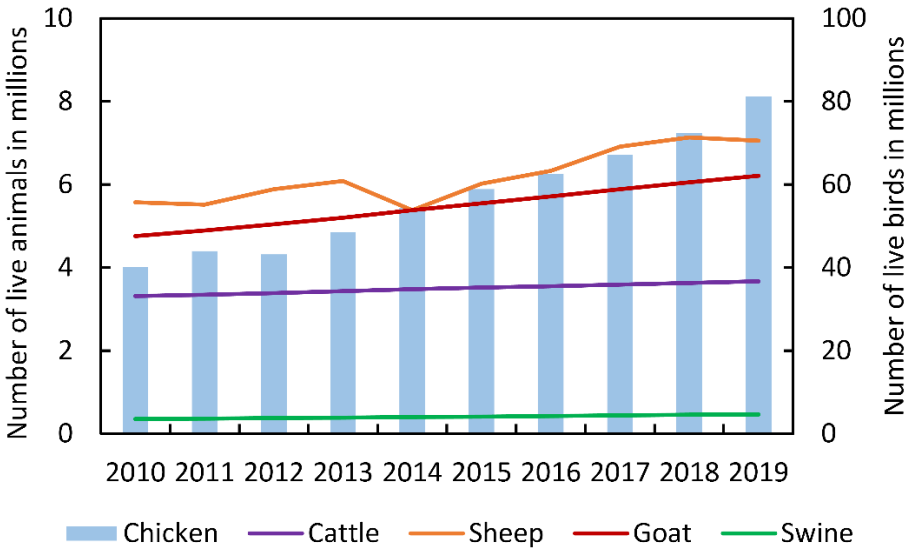

Figure 4. Total number of livestock species in Senegal during the period of 2010–2019 [47].

Pearl millet, groundnut, rice, maize, and cowpea can be identified as the major crops and an integral part of the mixed crop–livestock system practiced by agropastoralists in Senegal [47]. Although the total production of these crops shows an increasing trend, the largest variations in key crops such as millet and groundnut demonstrate the vulnerability of the sector to environmental stresses such as heat and drought (Figure 5a). Moreover, there is no substantial improvement in the crop yields, and in contrast, the yield of rice shows a declining trend (Figure 5b). Due to insufficient local production of rice, Senegal imports majority of the rice, which represents 75% of total cereal imports [48].

The import and export figures of livestock products are presented in Table 1, which shows the increasing dependency of the country on livestock products, especially beef, sheep meat, swine meat, milk, and eggs. In general, a greater amount of foreign exchange is involved in importing beef, milk, and eggs. This dependency on imports for livestock products is persistent in most of the Sahel and West African countries, where there is inadequate growth of local livestock production and an increasing imbalance between supply and demand. Meanwhile, a small extent of animal products is exported to countries such as Mauritania, Guinea-Bissau, Mali, The Gambia, and Burkina Faso [48].

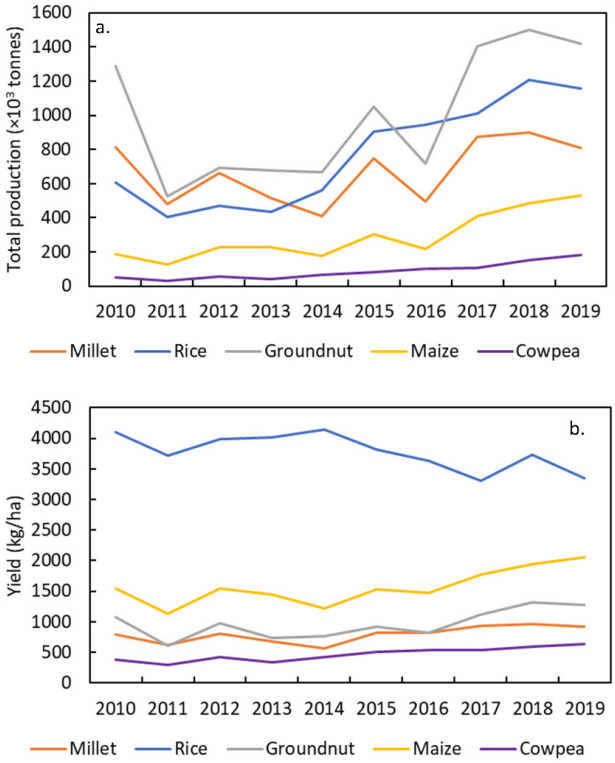

Figure 5. The total production of major crops (**a**) and their productivity (**b**) in Senegal for the period of 2010–2019 [47].

Table 1. Quantities and values of key livestock products traded in Senegal during the period of 2010–2019.

Year	Trade Quantity of Livestock Products in Tons (Trade Value, × USD 1000)									
	Beef		Sheep Meat		Swine Meat		Milk *		Egg	
	Import	Export	Import	Export	Import	Export	Import	Export	Import	Export
2010	5676 (9699)	63 (347)	111 (649)	13 (76)	101 (304)	8 (26)	39,406 (110,797)	4198 (13,401)	1064 (6841)	10 (87)
2011	4410 (9032)	18 (159)	63 (499)	11 (89)	96 (331)	2 (6)	28,361 (93,853)	4132 (19,317)	1196 (7537)	25 (196)
2012	3751 (8205)	9 (15)	138 (762)	0 (0)	73 (258)	1 (3)	27,142 (76,568)	5579 (22,511)	974 (5668)	16 (111)
2013	2715 (6748)	65 (409)	322 (1270)	42 (274)	132 (490)	3 (11)	18,911 (55,989)	9064 (37,782)	957 (5448)	19 (137)
2014	2582 (6057)	22 (178)	234 (904)	19 (178)	119 (401)	N/A (N/A)	19,519 (62,048)	3086 (13,206)	1088 (6650)	9 (69)
2015	2862 (5458)	10 (71)	182 (818)	2 (17)	121 (330)	1 (5)	23,352 (53,526)	3532 (10,746)	1567 (7367)	9 (64)
2016	3206 (5042)	22 (176)	188 (829)	10 (80)	89 (223)	9 (56)	22,005 (44,928)	2482 (7393)	2267 (10,575)	7 (42)
2017	3535 (6608)	109 (414)	234 (1236)	9 (88)	122 (396)	9 (57)	17,546 (38,211)	1596 (4650)	2463 (12,019)	21 (90)
2018	4146 (6717)	402 (827)	86 (409)	8 (71)	95 (269)	3 (18)	19,419 (45,949)	1995 (6443)	2345 (12,300)	12 (65)
2019	3986 (6552)	327 (571)	146 (690)	5 (47)	135 (297)	0 (0)	18,110 (43,052)	1208 (3468)	2177 (10,639)	50 (237)

* Total traded milk consists of skimmed dry milk, whole condensed milk, whole dried milk, whole evaporated milk, and whole fresh milk. N/A: data not available. Source: [47].

Among meat types, beef is imported in large quantities, while trading of goat meat and chicken is negligible. The majority of the milk is imported from Europe as dried and fresh cow milk. The US Department of Agriculture (USDA) reported in 2007 that the milk import is approximately twice the amount of local milk production measured in fluid milk equivalent, although milk imports show a declining trend in recent years (Table 1). In addition, livestock feed items such as alfalfa, cotton seed cake, and maize bran were also imported sporadically [47]. This shows the increasing demand for livestock products in Senegal while highlighting the importance of exploring the challenges that hinder the production potential of the livestock sector.

3.4. Challenges of the Livestock Farming

Major challenges for livestock farming in Senegal are pasture and feed availability, water resources availability, breeding and management of livestock species, international trade, climate change and variability, and socioeconomic constraints. The following section will discuss each of these challenges in more detail.

3.4.1. Pasture and Feed Availability

Livestock production mainly depends on the seasonal availability of pasture in the rangelands of the arid zone and the availability of crop residues in the agricultural areas of the semiarid and sub-humid zones. Thus, the supply of pasture and feed determines the stocking capacity. Therefore, the biomass production of grasses in the rangelands and crops in the agropastoral system and its availability as livestock feed determines potential productivity. According to Hiernaux et al. (2009), the biomass production of annual grasses in the Sahel region (i.e., arid zone of Senegal) ranges between 700 and 1300 kg dry matter (DM)/ha, which shows a greater interannual variation in biomass production and species composition [49]. These variations result from rainfall distribution, drought stress (intensity, timing, duration), soil type (fertility), topography, and geomorphology [25]. As a result, overgrazing often occurs in rangelands and leads to soil fertility depletion, soil erosion, and land degradation [11]. It is also important to highlight that forage quality (e.g., nutritive value, palatability, digestibility) generally declines along the north to south (i.e., Sahaleian zone to Guinean zone) direction within the country, even though the forage quantity increases along the same direction [2]. The reduced forage production is linked more to the limited availability of nitrogen in the soils of Southern Sahel than to water. Nitrogen deficiency and low soil organic carbon content were identified as the most limiting factors in West Africa [50]. Low soil nitrogen results in poor plant growth and protein content in biomass and grain. Therefore, the crude protein content of forages ranges between 3% and 6%, while in the Northern Sahel, crude protein content is much higher, up to 12%, regardless of water limitation [25]. Remarkably, pastoralists have substantial knowledge of the diversity of pasture species, habitat types, seasonal changes in quality and quantity, trends, and drivers of change, which helps them find feeding resources for their herds [51]. Moreover, different livestock species have varied requirements of fodder intake, and the availability of fodder varies seasonally in the rangelands [52].

In the West African agropastoral system, Fernández-Rivera et al. (2004) quantified that crop residues could provide 360 kg DM per year for each tropical livestock unit (TLU) (i.e., 1 TLU = a hypothetical animal of 250 kg of live body weight) [17]. This would be only adequate to cater to each TLU for about two months per year; however, the requirement lasts for three months to cover the dry season each year [17]. According to Assouma et al. (2017), a typical sylvo-pastoral system in the semiarid zone of Senegal may support a stocking capacity of 0.11–0.39 TLU per hectare, depending on the seasonal movements of the livestock [53]. Meanwhile, cereal residue availability is greater than leguminous hulls and peels of tubers, and most of these cereal residues come from millet, sorghum, rice, and maize in the region. In contrast, Senegal leads in the production of leguminous hulls, which come from its unique groundnut-based system. The pearl millet–groundnut–livestock system and rice–groundnut–rice–livestock system that are predominant systems in Senegal

are estimated to produce 497 kg DM per year and 583 kg DM/ha, respectively, for each TLU, which is generally insufficient to meet the feeding requirement [17]. In some regions, the plants are completely pulled out of the ground with roots, which has a negative impact on soil organic carbon and soil health.

Meanwhile, attempts to introduce cultivated perennial forage legumes such as Gliricidia (*Gliricidia sepium*), Ipil-ipil (*Leucaena leucocephela*), *Sesbania* sp., Pigeon pea (*Cajanus cajan*), Drumstick tree (*Moringa oleifera*), herbaceous legumes, and perennial grasses, such as Guinea grass (*Panicum maximum*), Crabgrass (*Digitaria unfolozis*), and Congo grass (*Bracharia ruziziensis*), have been taken as part of livestock development projects [54,55]. However, these attempts were not successful due to harsh climatic conditions, poor availability of inputs (i.e., seeds, planting materials, fertilizers), lack of financial support, sociocultural aspects, and limitation for knowledge and technical know-how on well-adapted forage species. There were very few targeted research programs on breeding or agronomy of identifying low input forages when compared to food grain crops. Such programs need to be promoted to improve the yield and quality of forages. In addition, a limited extent of agroindustrial byproducts, including cereal brans, seed cakes, and molasses, are used in off-land systems. Senegal also imports a certain amount of animal feed, such as soybean cake, sunflower cake, and wheat bran. Nevertheless, formulated commercial feed availability is comparatively better for monogastric animals (i.e., pigs and poultry) because of the few large-scale commercial feed mills in Senegal. Local production of formulated feed often demands cereals and imported fish meal and soy meal, which have competing uses and economic impacts, respectively. Lower purchasing power, irregularities in the supply chain, and lack of quality assurance hinders the use of concentrates and formulated feed, which is the major constraint for the intensification of livestock farming in Senegal and West Africa.

3.4.2. Water Resources Availability

Water is one of the limiting resources for livestock farming in Senegal and determines the mobility of herders in addition to pasture [16,23]. Surface water bodies, including rivers, ponds, and lakes, are available for livestock during the rainy season, while they are limited to groundwater resources such as wells and boreholes during the dry season [56]. Water scarcity is severe in the northern region, and colonial hydraulic developments, such as water points, do not serve all the areas. Limitation to water is another obstacle for the utilization of available pasture because where there is pasture, water is not available, and where there is abundant water (i.e., perennial waterbodies), quality pasture is lacking [9]. However, the southern region has rivers, tributaries, interconnected lakes, and groundwater resources that provide water for crop and livestock production [57].

In the late 1980s, dams were constructed along the Senegal river with the scope of promoting local rice production. However, modifications to river flow have caused several environmental, health, and social problems that have outweighed the benefits such as the development of agroindustry [58,59]. Furthermore, dams and dikes construction has led to significant loss of pastureland and reduced the feeding potential from 8928 to 446 TLU [60]. Most of the water points along the transhumance routes and corridors are not properly operating, and water scarcity also leads to conflicts between pastoralists and farmers. Therefore, international agencies such as the World Bank have implemented development programs to rehabilitate several existing water points and construct new ones to support livestock farming [61]. Due to the severe nature of water scarcity in this region, any form of development that improves water availability often will have a positive impact on livestock production and the livelihood of pastoralists.

3.4.3. Breeding and Management of Livestock Species

Livestock across West Africa are diverse and have well-adapted native breeds and ecotypes. In addition, pure and crossed exotic breeds have also been introduced to intensify livestock production in some regions. However, most of the imported breeds and cross-breeding programs were not successful in West Africa [62]. Among domestic cattle species,

zebu (*Bos indicus*) breeds and stabilized cross-breeds (*B. taurus* × *B. indicus*) dominate in the Sahelian and Sudanian zone because of their adaptability to drought, high temperature, and poor-quality forage [2]. Moreover, these breeds (e.g., Fulani cattle) have large body sizes and predominantly represent the transhumant pastoralism in Senegal [16].

Meanwhile, taurine breeds (*Bos taurus*) are the major cattle species in the sub-humid (Guinean) zone and an integral component of the endemic ruminant livestock in West Africa. Endemic ruminant livestock such as N'dama cattle, Djallonke sheep, and West African Dwarf goat are well-adapted to the sub-humid zone due to their inherent tolerance to trypanosomiasis disease [16,63]. Trypanosomiasis, or sleeping sickness, is a vector-borne disease spread by tsetse fly, which is highly infested in the sub-humid zone [64]. Furthermore, endemic ruminant livestock have a smaller body size in comparison to zebu breeds, thus having lower requirements for feed, water, nutritional intake, and animal husbandry, therefore they are suited for the agropastoral system in Senegal. These endemic species also show heat tolerance and resistant to parasitic worms and tick-borne diseases [16]. In contrast, zebu breeds are susceptible to trypanosomiasis [65,66]. Therefore, trypanosomiasis acts as a natural barrier for Sahelian breeds and transhumant herders to exploit the pasture resources in the sub-humid zone. However, with the availability of trypanocidal drugs at subsidized prices and deforestation, herders from the Sahelian zone increasingly move their animals into the deep south to graze pastures in the sub-humid zone. This increasing mobility of zebu breeds into the habitats of endemic ruminant livestock species leads to their extinction and assimilation due to the degradation of the ecosystem, cross-breeding, and abandonment due to production and market constraints [16].

Pastoralists and farmers give importance to tolerance traits to drought, heat, and pasture scarcity in selecting breeds of cattle, sheep, and goats for pastoral systems in Senegal. For example, the selection of longhorn traits in cattle aims to dissipate heat and minimize the loss of productivity in the high-temperature environment [67]. Meanwhile, the genetic potential of these native breeds to deliver greater productivity is generally low. Low-input environment, especially in Sahelian and Sudanian zones, is another reason for the lower livestock productivity. Meanwhile, the majority of the efforts taken to adapt pure exotic breeds of cattle (e.g., Indian Sahiwal, Jersey, Friesian, and Brown Swiss), sheep, and goats and to introduce exotic gene pool into the local animals have failed due to the harsh environment and lack of technical support [62,68]. In addition, the possibility of implementing new interventions in this region to address these challenges in the foreseeable future is very low [69]. In exception, exotic breeds of pigs and poultry are popularly raised in Senegal's urban and peri-urban systems [2]. Moreover, institutional support for breeding, breeding programs, and extension services targeting native and adapted breeds are far behind or not available to pastoralists and farmers [70].

Animal husbandry and management are mainly traditional and lacking in proper shelters for animals. Socioeconomic constraints, limited extension services, and risky environment for foreign investment are some of the reasons behind the poor adaptation of new equipment and infrastructure [71]. In pastoral systems, livestock species are considered as more cash source and prestige than productivity-based. Therefore, the number of animals is prioritized over productivity, and extensive management is practiced. Although traditional practices and regulations have been followed to access pasture and water points in the past, most of these practices are currently abandoned due to demographic changes and climate extremes, leading to greater number of animals competing for pasture and water resources, which causes land degradation. In addition, management challenges include poor livestock infrastructure (e.g., roads), water resources, markets, and animal healthcare, further reducing livestock farming's production potential in Senegal.

3.4.4. Marketing and International Trade

In Senegal and other West African countries, livestock farming's primary objective is to meet the subsistence requirements of livestock products for the household and relatives, but concerning the marketing side of livestock productions, live animals' sale as a cash reserve

is very common; however, some degree of small-scale animal trades is also present [29]. The local market system heavily depends on small networks of exchange-based channels that operate under personal and ethnic relations [2].

In Senegal, there are distinct differences among livestock farming systems in terms of access to market and trading opportunities. Pastoralists who are highly populated in the northern Ferlo region and southeastern Senegal are usually kept out of the meat markets except during religious festivals (e.g., Tabaski/Eid al-Adha) when meat demand is high [72]. In addition, pastoralists use traditional methods in milk collection, and their distribution is mostly limited to rural areas. Although the majority of the local raw milk is produced from the pastoral system, its production is irregular, where large quantities of milk are produced during the short rainy season and spoiled due to poor market access and lack of opportunities for processing. Few efforts of implementing contract schemes between milk processors and pastoralists also failed due to poor hygienic conditions in the pastoral system [20]. In contrast, some appreciable efforts are currently taken by La Laiterie du Berger that enable local milk producers to have regular revenue by purchasing their milk for processing and value addition. Marketing of poultry products in the pastoral system faces several constraints, including geographical dispersion, poor reproductive performance of local birds, diseases, and higher transaction costs [72]. Overall, pastoralists have many limitations for marketing opportunities due to irregularities in livestock production and scattered markets to feed the meat demand in the cities actively.

Agropastoralists in the Groundnut Basin have greater connectivity to Senegal's capital Dakar, and, thus, are comparatively in a better position for market access than pastoralists [72]. Connectivity to the cities makes them available for supplementary feeds and market ventures for meat and milk. Poultry, swine, and intensive milk production units from the off-land system in urban and peri-urban areas are supported by government and non-government agencies, or large-scale companies who often have better assurance for marketing [8].

Lack of transport infrastructure, cold storage, and processing facilities are additional constraints for marketing. As a result, most animals are traded as live animals without value addition and irrespective of the risk of transmitting transboundary animal diseases. A bargaining approach is used to determine the price of the animal rather than a live-weight-based method, and the involvement of many intermediate players leads to higher prices. Moreover, institutional support and government policies are not well aligned with strengthening local and external markets and promoting market access to producers. Regarding international trade, Senegal is not self-sufficient in livestock products and heavily depends on imports to meet its meat, milk, and eggs national demands (Table 1). For example, Senegal was identified as one of the largest importers of live animals in West Africa, and these animals are imported mainly from Mali, Mauritania, and the Netherlands. With ever-increasing demand for livestock products in the future, especially among the higher- and middle-income population in urban areas [73], it is vital to substantially improve the marketing channels and international trade in Senegal. Improvement in market strategies also helps the farmers cope with challenges such as climate change. There are observations showing that livestock producers and traders have changed their strategies to catch up with emerging marketing opportunities. Further improvements should harness the social construction of livestock markets and marketing behaviors as adaptive strategies [74].

3.4.5. Climate Change and Variability

Anthropogenic climate change and associated variability in the regional climate are the major threats to the food and nutritional security in West Africa, including Senegal [75–77]. The direct effects of climate change include increasing ambient temperature and rainfall variability, seawater intrusion, and increasing extreme events such as droughts, floods, and heatwaves [45,78,79]. In Senegal, the average temperature increase is 1.6 °C since 1950, with this increase being much higher (~3 °C) in the northern Sahelian zone [43]. Moreover,

current temperature projections indicate an increase between 1.8 °C to 4 °C by the end of this century, with the greater increase expected in the inland, rather than coastal, areas [43,79]. Meanwhile, the rainfall projections are often uncertain and controversial, while most of the climate models predict erratic rainfall events in Senegal [45,80]. According to Ickowicz et al. (2012), the interannual variability of rainfall in the Sahelian zone is high with a coefficient of variation of 30% [81]. In addition, due to the stormy nature of monsoonal rainfall, it is highly variable both in time and space. Increasing rainfall variability often causes prolonged droughts and floods, while sea-level rise leads to saltwater intrusion in coastal regions.

The impacts of climate change on livestock farming depend on agroclimatological conditions, farming systems, demographic changes, economic development, and the interactions among them [6,16]. Climate change and variability have both direct and indirect effects on livestock farming in Senegal. Direct effects of climate change on livestock are mainly related to decreasing production performance due to the negative impacts on animal metabolism, weight gain, feed conversion efficiency, reproductive performance, immune response, and health status of the animal [82,83]. Indirect impacts are associated with how climate change and variability affect feed availability, water availability, and management for livestock species and livestock food supply chain [81,82,84]. In an extensive management system with breeds well adapted to high temperatures and droughts, such as pastoral and agropastoral systems of Senegal, indirect impacts are more critical than the direct impacts of climate change, while direct impacts are mostly relevant to the off-land system. Furthermore, livestock in this region being the source of greenhouse gas emissions may contribute to global warming [85]. For example, Ndao et al. (2020) estimated an annual methane emission factor of 30.7 kg CH_4/head/year for lactating cows and 15.1 kg CH_4/head/year for other cattle in Senegal [86]. However, these values were far below the default emission factors proposed by the Intergovernmental Panel on Climate Change (IPCC).

In the pastoral system, drought affects the pasture production and water availability to the livestock farming [87,88], especially in arid and semiarid zones. Declining trends of water levels were observed in the major surface water bodies, such as the Senegal river, as a result of frequent droughts [43,89]. In addition, the increasing frequency of flood events impairs livestock farming in the low-lying areas of Dakar and northwestern Senegal [43]. Climate change also impairs pastoralists' routes and direction in search of pasture and water for their animals [85].

Meanwhile, agropastoralists highly depend on crop production to feed their livestock. Therefore, any impacts of climate change and variability would have negative consequences for livestock farming in the agropastoral system. Process-based crop models and spatial-scale studies highlight a declining trend of yields for major crops in Senegal in response to climate change [90,91]. Crop production shows vulnerability to climate change significantly in the Groundnut Basin [77], and because the majority of the cropping areas (~97%) are under rainfed agriculture [80,90]. For example, the yield of groundnut was projected to decrease between 5 and 25% as a result of climate change in Senegal [90]. Moreover, the use of seasonal climate forecast information in the herd management decisions was minimum and limited among the agropastoralists [92].

Saltwater intrusion has been observed to impact the country's rice production [43], and with the narrowing length of the growing season due to droughts, rice production has become not viable. For example, the Sahelian drought of 2010 and 2012 caused large-scale crop failure and led to food insecurity in most West African countries [87]. Moreover, climate change is also projected to decrease the suitable areas for crop production [93]. Impacts of climate change and their effects on crop harvests were recognized by the farmers in this region [94,95]. However, the agropastoral system is comparatively resilient to the impacts of climate change relative to the pastoral system [43]. Hence, integration of livestock and crops is considered to be an evolving adaptation strategy of local farmers in response to climate change [16,30].

3.4.6. Socioeconomic Constraints

Socioeconomic pressures are another set of constraints limiting livestock productivity in Senegal and West Africa. Increasing population (growth rate is around 2.25%), deforestation, and unplanned expansion of crop cultivation has led to resource competition and intervened in the transhumance pastoralism in Senegal [19,27]. The West African region has a communal land tenure system with some variations between countries in the north and the south [2]; however, lack of security in land tenure is still a huge problem for many herders [71]. In the sub-humid zone, first-settlers are the ethnic majority and have political dominance over recent immigrants (i.e., agropastoralists) and transhumant pastoralists [16]. Hence, these pastoral communities lack political power and institutional support regardless of their legal rights to common-pool resources (i.e., pasture, water). The top five limiting socioeconomic factors in West Africa were identified as access to financial resources, availability/capacity of public sector extension, land tenure, availability of private sector providers, and access to mechanization [50].

Most of the livestock farmers are smallholders and are deprived of financial resources such as loans, credit schemes, and insurance. Although adult males predominantly manage livestock farming, women and children play significant roles in livestock-related livelihood operations. Most of the small ruminant species and poultry are managed by women and the younger population. Moreover, women are more involved in managing milk collection, processing, and value-addition due to its relevance to child nutrition. However, the productivity of women-managed livestock systems is often lower than the ones managed by men because of limited access to inputs, extension services, and modern techniques, in addition to social barriers [96]. Additionally, greater involvement of children and youth in livestock farming affects their educational opportunities, which in turn leads to a high level of illiteracy rates, lack of technical skills, and loss of productivity [71].

3.4.7. Other Constraints

Animal health care is very limited, especially in the pastoral zones of West Africa, due to the lack of trained personnel and local manufacturing of veterinary products. Meanwhile, animal health services in Senegal have deteriorated following the complete privatization of veterinary care [2]. Because of this limitation, livestock species have been periodically exposed to various animal, avian, and zoonotic diseases. Due to the transboundary movement of millions of livestock across multiple countries in West Africa, they are drivers of spreading animal diseases across the regions. In addition, these animals are carriers of vectors and transmit the disease when they encounter the local livestock. Furthermore, there is a likelihood of transmission of diseases from livestock species to humans, such as Ebola, that can have serious implications for human health, especially in intensive urban and peri-urban systems [97,98]. Therefore, animal health care is critical and needed.

The livestock sector is also affected by poor institutional capacities for research and extension due to limited investment and lack of funding for capacity development [3,6,71]. Moreover, most of the current policies are ineffective and outdated, thus not supporting the growth and development of the sector. Lack of reliable livestock production statistics is the primary reason for ineffective policies [99]. Meanwhile, transhumance pastoralism is often endangered by civil unrest in many West African countries. For example, the Casamance conflict substantially affected livestock farming in Senegal between 1982 and 2014 [90]. In addition, transhumance pastoralism poses a threat of spreading invasive alien species [16].

3.5. Actionable Ideas

The constraints for livestock farming also provide ample opportunities for actions to improve the current status of different livestock farming systems in Senegal. Possible interventions to overcome these constraints are detailed in Table 2. Although these actions require proper planning, financial resources, administration, and long-term commitment, they have the potential to increase the productivity of livestock farming, thereby improving

the livelihood of herders and farmers in the region. On the other hand, some interventions need to be carefully designed. For example, the application of crop residues in conservation agriculture creates scarcity of the same residues for livestock feed. Lack of crop residues pushes farmers to move their animals outside the agricultural areas, which leads to the loss of manure contribution to the farming system. Recent studies showed that yield increase due to soil moisture retention under conservation agriculture did not compensate for yield losses resulting from reduced manure availability for crops [100]. Complete removal of crop residues further exacerbates the poor soil carbon and soil health, negatively impacting biomass production. Livestock can be a good source of nutrients if the manure is properly managed and applied to the soils. Similarly, considering the rapid increase in fuel requirement, which traditionally is obtained from cutting trees for making charcoals, generation of biogas from livestock manure provides a good alternative. These multiple issues and opportunities for synergies and trade-offs highlight the importance of co-designing effective management interventions considering site-specific requirements.

Table 2. Potential interventions to overcome the challenges of livestock farming in Senegal.

Challenge	Interventions for Improvement	References
(1) Lack of pasture and feed availability	• Regional monitoring of the seasonal availability of pasture composition and quality. • Producing real-time pasture availability information accessible to pastoralists. • Greater integration of crop-livestock systems. • Incorporation of harsh climate-adapted annual and perennial legumes into the agropastoral system. • Improving agricultural productivity by improving the accessibility to fertilizers, quality seeds, and agricultural equipment. • Strengthening indigenous farming practices. • Enhancing the production capacities of commercial feed mills. • Establishing quality assurance of commercial and formulated feed.	[2,11,90,101–106].
(2) Scarcity of water resources	• Renovating pastoral water points and boreholes near the pasture lands. • Constructing small reservoirs and rainwater-harvesting methods. • Efficient utilization of water resources in the Senegal river development plan. • Implementing water-saving and climate-smart agriculture within the agropastoral system.	[9,61,105,107,108]
(3) Breeding and management of livestock	• Preservation of endemic ruminant livestock species. • Incorporating pastoralists' concerns and experiences into the selection and breeding programs. • Providing institutional support for the breeding of native and adapted breeds. • Financial support to improve animal husbandry and infrastructure.	[2,16,109]

Table 2. *Cont.*

Challenge	Interventions for Improvement	References
(4) Marketing and international trade	• Improving storage, processing, and transport for livestock products. • Strengthening local market channels and eliminating the middlemen. • Maintaining appropriate sanitary and hygienic conditions in milk collection and processing centers, slaughterhouses, and meat markets. • Development of policies in support of local and external markets. • Improving the product quality along the supply chain.	[9]
(5) Climate change and variability	• Better integration of crop–livestock systems. • Introducing drought-resistant crops such as cowpea and cassava, which can be cultivated in degraded soils. • Developing crop varieties with tolerant traits to drought, heat, and salinity stress. • Efficient utilization of water resources for crop cultivation and promotion of conservation agriculture. • Enhancing extension services to disseminate techniques of climate change adaptation and climate smart agriculture. • Strengthening weather monitoring and seasonal climate forecasting to predict droughts and floods. • Establishing accessible early warning system for farmers to plan cropping system before the onset of rain. • Improving the housing conditions of off-land system to mitigate the direct effects of climate change on animals. • Feasible insurance schemes for farmers and herders.	[43,45,77,88,90,110–112]
(6) Socioeconomic constraints	• Regulating the extraction of forest resources and expansion of cropping areas. • Strengthening sociopolitical and institutional support for all pastoral communities. • Improving land tenure and equal access to livelihood resources/education for vulnerable groups such as women and children. • Opening ventures for income diversification. • Providing financial support for herders and farmers.	[6,71]
(7) Poor veterinary care	• Increasing animal health care facilities in remote villages. • Improving disease surveillance in pastoral areas. • Offering governmental subsidies for the local production of veterinary goods. • Training human resources for veterinary care.	[2,6,9]
(8) Weakened institutional capacities	• Strengthening local institutions for livestock research, development, and outreach.	[6]
(9) Ineffective livestock policies	• Synthesizing livestock statistics for better planning and policymaking. • Revisiting current livestock policies and improve them to better support livestock farming.	[88]

4. Concluding Remarks

Livestock farming is vital for the economy, food, and nutritional security of West Africa and Senegal. The livestock farming in Senegal has also been shaped by demographical, economic, environmental, and sociopolitical challenges. Meanwhile, agroclimatic conditions eventually determine the type of livestock farming system. Accordingly, the pastoral system is dominant in the arid and semiarid zones, while the agropastoral system is dominant in sub-humid savannah zones. The majority of the local meat is produced from the pastoral system, where herders seasonally mobilize the animals in search of

pasture and water. In the agropastoral system, pearl millet–cowpea–livestock integration is popular across West Africa. However, Senegal's agropastoral system has two unique crop–livestock integrations, namely, the pearl millet–groundnut–livestock system and the rice—groundnut–livestock system. Crops in these systems are often grown as rainfed with a smaller extent of irrigation. The wide dissemination of dual-purpose crops, on which the Senegalese agricultural research system is currently working hard under Feed the Future initiatives, may come out with better agriculture–livestock integration while reducing transhumance and farmer–pastoralist conflicts. However, the technical aspect is not the only option, and other limitations have to be unlocked, such as value chain organization, adapted trade policies, support to rural infrastructures, institutional capacities, and training for farmers. The off-land system is practiced as intensive or semi-intensive, concentrated around urban and peri-urban areas, consisting mainly of poultry, swine, and milk cattle. Hence, the majority of the poultry meat, pork, and eggs are produced from this system.

The data and research showed that, due to frequent droughts, pastoralists have begun to raise more small ruminants, which are considered to be more resilient to harsh climates. As a result, the growth in the numbers of goats and sheep was higher than that of cattle in the recent past. Furthermore, Senegal will continue to be heavily dependent on imports to meet its demands for major livestock products, especially beef, milk, and eggs, regardless of potential improvements in productivity. The major contribution of this work is the identification of main challenges that limit production of the livestock farming sector in Senegal while summarizing the potential interventions for improving the overall performance of this sector with broader perspectives for West Africa. The findings of this systematic review and proposed interventions may be broadly applicable to countries with similar socioeconomic profiles as well as an agroclimatological and physiographic gradient by which the livestock systems are shaped. In many countries, increasing population and income demand more animal protein as the quality of life improves. Hence, these interventions should be prioritized to maximize the synergies of productivity improvement in the livestock farming regions with similar constraints and prospects.

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