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Review Article

Climate Change Impact on Small-Scale Animal Agriculture: Livestock Water & Food Security in Africa

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Abstract: Water is essential for food security and animal agricultural productivity, but it is becoming more scarce due to climate change. The interaction between climate change and livestock water resources has received little attention from researchers, despite the significance of small-scale animal husbandry for the rural poor in Africa and the size of the changes that are anticipated to have an impact on smallholder livestock systems. Threats to livestock water are undoubtedly one of the most significant environmental issues that have impacted food security on the continent, given their links to small-scale animal husbandry and the detrimental impacts on productivity. In order to balance the negative effects of climate change scenarios for sustainable animal productivity and contribute to food security through small-scale animal agriculture, the most climate-smart and resilient agricultural water practices and technologies must be used. Changes in rainfall and a decline in the biomass available for grazing and rangelands as a result of water stress brought on by the climate would have the most severe effects. This is due to the rain-fed nature of small-scale livestock farming. The local animal genetic resources are essential for animal productivity and food security in Africa, particularly in areas where livestock water is becoming scarce owing to climate change. Research and development goals on the effects of climate change on livestock water, animal productivity, and food security may need to be reviewed if demands of vulnerable small-scale animal producers are to be successfully addressed in the future decades. It is best to use an interdisciplinary approach to comprehend the relationships between small-scale animal husbandry, food security, and climate change. By navigating the complexities of climate adaptation, small-scale livestock farmers can manage livestock water scarcity by taking adaptation measures that are in line with evolving climate impacts and associated means of implementation based on pertinent and useful knowledge that takes into account a blend of traditional and modern water science. In this paper, an effort is made to close some significant information gaps and shed light on how water-induced stress impacts small-scale animal production, which has an effect on food security.

Keywords: Climate Change; Small Scale Animal Agriculture; Livestock Water; Food Security

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1. Introduction

Population growth and climate change are expected to significantly aggravate water shortages for huge areas of humanity [1], putting a damper on livestock productivity and, as a result, food security. In sub-Saharan Africa, small-scale animal farming is one of the key elements of agricultural water use [2]. Climate-related water scarcity, lack of access, and inadequate and wasteful use of livestock water by smallholder animal farmers in Africa pose a risk to animal production. These uncertainties put animal output at risk, which has repercussions for food security. The predicted effects of climate change on hydrology and water resources may differ in different river basins depending on the hydrological model, climate change scenarios, and downscaling strategies used [3]. Heat stress appears to be the primary factor negatively influencing cow productivity, reproduction, and growth due to a water deficit brought on by climate change. Agricultural water demand must be kept from rising in light of the growing global demand for food.

Arid and semi-arid tropics are characterized by a lack of water for livestock, which frequently exacerbates the effects of heat stress in animal hence compromising performance. Due to a water shortage brought on by climate change, heat stress appears to be the main factor severely affecting cow productivity, reproduction, and growth [4]. Depending on the hydrological model, climate change scenarios, and downscaling techniques employed, the expected consequences of climate change on hydrology and water resources may vary in different river basins [5]. In light of the expanding global food demand, agricultural water consumption must be restrained by developing methods to produce more with a given amount of water.

Small scale animal agriculture animal output has been negatively impacted by the consequences of declining water supplies and occasionally exceptionally high temperatures that are stressful for animals [6]. Various measures are taken by communities to deal with these issues, adapt to the environment's changes, and halt further climate change (mitigation). According to [7], the only feasible and dependable way to increase agricultural production's productivity, sustainability, and resilience under anticipated climate scenarios is to combine traditional management practices with agro-ecologically based management practices (bio diversification, water harvesting, etc.). Given the aforementioned, it is essential to determine how climate change is affecting water consumption and livestock production in order to develop viable new technologies for adopting a climate-smart water-smart approach [8].

The continent's small-scale animal husbandry sector is diverse and complicated, providing a variety of needs in local communities. Therefore, any effort to promote climate-smart water agriculture practices must recognize and respect these realities of socio-cultural and economic farmers' livelihoods in order to achieve long-term, sustained adoption of a changed approach that fosters resilience in agriculture, especially livestock water. The fundamental objective of this discussion is to illustrate the connections between climate change, small-scale animal husbandry, livestock water resources, and food security. As production must rise to accommodate the anticipated population growth, the effects of climate change on small-scale animal husbandry on rural livelihoods and food security are becoming increasingly clear. In order to effectively manage livestock water resources and enhance animal output for food security, particularly in Africa, it is necessary to prudently preserve and conserve these resources for long-term use.

2. Water consumption by livestock: a global perspective on a local issue?

Climate change, population growth, polluted water supplies, shifting land use, and economic change will all lead to a rise in the global demand for water [9]. In many parts of the world, the inability to meet the demand for high-quality water has now reached a crisis point. Concern is raised about how to meet the water needs for food production for the expanding global population, which is predicted to reach 9.8 billion people by the year 2050 [10]. According to estimates, by 2055, 64% of the world's population would reside in basins with water stress and 33% in regions with severe water scarcity [11]. According to [12] noted that just 3% of the freshwater resources on Earth, including those used for agriculture, are available for human use.

In arid and dry areas of the world, water stress is noticeably more severe, and seasonal drought vulnerability is increased. According to predictions provided by [5] more than thirty countries would experience water stress by 2025 compared to seven in 1995. However, [1] claimed that water scarcity is expected to worsen for a significant chunk of humanity as a result of both population growth and climate change. Agriculture is the world's largest user of water, using 69% of all freshwater withdrawals and an even larger portion of all freshwater consumption, making it one of the most crucial resources for agricultural output [12] and 72% of global water use is for agriculture, according to [11].

If the rising need for livestock products is taken into consideration, food consumption is predicted to rise by 70–90% by 2050. Compared to the 7000 km3 already used globally to produce food and feed, this will require an additional 5000–6000 km3 of water yearly [13]. Due to this, water shortages are predicted to worsen significantly. By 2025, 4 billion people will live in water-stressed countries, according to [14], compared to 3 billion according to [15], with sub-Saharan Africa and South Asia having the highest concentration. Currently, 70% of the water in the globe is used for agriculture. As a result, the demand for water resources will only increase if more food needs to be produced to feed the world's population now and in the future. There will be significant trade-offs between ecological services and agriculture. [16] and [17] and others have all documented the negative effects of the current over-exploitation of finite water resources in crop-livestock systems.

These effects include declining groundwater levels, decreasing river flows, worsening water pollution, declining lake levels, and deteriorating wetland systems. Despite rising food consumption, particularly for food derived from animals, there will be less water available for agriculture and food production [18]. In these situations, a lot more details are required in order to carry out a more thorough quantification of the problem's scope. The implementation of suitable policies to solve the sustainability and water allocation challenges, which in the future may be significant, could be sparked by such knowledge [19].

The production of feed crops, forages, and grazed biomass requires an annual appropriation of 4,387 km3 of both green and blue water by the world's livestock sector [20]. It is extensively contested to what degree and how livestock fit into the equation of global water use. The livestock industry uses water for a variety of maintenance and product-processing purposes in addition to the water required on farms for drinking and the growth of feed crops. In addition to discussing the impact of livestock on water contamination, [11] present quantitative estimates of the direct and indirect water use in the livestock industry. They point to extremely significant variations in service water needs for various livestock systems, ranging from 0 l/animal/day in extensive grazing.

According to [21], livestock consume about 25 l/TLU of water per day, although the daily production of feed may demand 100–200 times more water [22]. This is important since the primary barrier to the development of livestock is generally a lack of feed, the supply of which is frequently dependent on rainfall. 64% of the world's population, up from 38% currently, will reside in water-stressed basins by 2025 [16]. There hasn't been much research done on how such supply shifts affect livestock and livestock systems in developing nations.

Although it is difficult to quantify the effects of climate change on water resources in land-based livestock systems in developing countries, there will likely be an increase in demand for water in situations where groundwater supplies a large portion of the water for cattle, as is the case in many grazing systems, for example. The need for policies that may address difficulties with allocation and efficiency will grow as water demand and competition increase over the coming decades in many locations. Because doing otherwise will negatively impact animal output and subsequently food security.

Water requirements for food production can vary widely, with directly plant-sourced food, such grains and vegetables, being produced in more water-use-efficient ways. For instance, the range for food supplied from plants is 0.5 m3/kg potato to 3 m3/kg rice, while the range for food sourced from animals is 3.5 m3/kg for broiler production to 100 m3/kg beef production [23]. The investigators arrived to the average conclusion that one dairy animal's daily feed required 10,000 L of water on average and that high water needs were related to feed production and resourcing. The average worldwide is 0.9 m3. Most livestock nutritionists are still ignorant that much more water is needed for evapotranspiration during the preparation of feed because traditionally, the relationship between livestock and water is related to drinking water requirements. Water requirement assessments are hardly ever employed in feed resource planning and ration design.

According to [20], the livestock production has assigned only 6% of its total Consumptive water use (CWU) for the manufacture of feed, which is much less than the 16.5% and 14.1% of blue water it has allotted for food crops and other purposes, respectively. This is because the CWU is supplemented with a large amount of green water from pastures, which are assumed to be entirely rainfed, as well as a smaller amount of blue water from forages and feed crops grown on farmland (9.8%). a lesser proportion of the 836 km3/yr. just 264 km3/yr of blue water used for food crops but of all blue water used in agriculture is used to produce animal feed.

[24] noted that while more intensive systems are typically linked to higher water needs, more extensive systems are frequently less productive in terms of the amount of agricultural yield from water intake. Furthermore [25] calculated that an average of 3.4 m3 of water is required for the production of 1 kg of milk, bringing attention to the occasionally surprisingly high water needs for extensive dairy production. Despite concerns about excessive livestock water use, animals have been noticeably missing from agricultural water research and development. Future assessments of water use and productivity must take this need into account because it is anticipated that the demand for milk and meat will increase by double over the next 20 years. Notions of water productivity have primarily been applied to agricultural production. It is crucial to characterize water productivity in river basins in all of its dimensions in livestock production systems.

In 2000, agriculture accounted for 70% of water consumption and 93% of the world's water use. 2004 [26]. It is predicted that worldwide freshwater use will rise by 10% from 2000 to 2010, down from a per-decade pace of 20% between 1960 and 2000, as a result of population growth, economic growth, and improvements in water-use efficiency. The main issue might be the uneven distribution of water. Between 1 and 2 billion people live in nations with a water deficit, which has an impact on agricultural production, human health, and economic growth, according to [27]. Regarding the probable effects of climate change on livestock's water needs, there is less ambiguity. It has been extensively examined how higher temperatures affect livestock's need for water. For instance, the water intake of the Bos indicus increases from about 3 kg/kg DM intake at 10 C ambient temperature to 5 kg at 30 C and to about 10 kg at 35 C. (NRC, 1981). At the same three temperatures, intake for Bos taurus ranges between 3, 8 and 14 kg/kg DM intake. Forage water content varies from close to 0-80% depending on species and weather circumstances, and some of this water intake comes from forage.

According to [28]'s calculations, a kilogram of beef has a water footprint of roughly 15,000 L. The overall amount of water needed by low-producing animals in pastoral rangelands, such as those in desert plains or high mountains, would be extraordinarily large if green water were factored into estimations (as in water footprints). While [23] did not explain the methodology employed, they did note that the computation was based on vast rangeland systems, which call for a sizable area for animal production. The amount of water used per kilogram of beef in research to date ranges from 27 to 200,000 L. [29, 30]. As previously mentioned, the methods and coefficients applied affect the findings (e.g., for evapotranspiration).

In contrast to attempts to quantify the effects of climate change on water resources in land-based livestock systems in developing countries, which are fraught with uncertainty, particularly in situations where groundwater accounts for a significant portion of the supply of water to livestock, as is the case in many grazing systems, for example, quantifying the response of livestock to known increases in temperature are predictable in terms of increased demand for water. Demand for and competition for water will grow over the coming decades in many locations, prompting the creation of policies that can handle issues with allocation and efficiency.

3. Ecosystem services linked to water, and food security in small scale animal agriculture

Water is a crucial but frequently disregarded nutrient. [31] suggested that ecosystem health has a significant impact on both the quantity and quality of water that is available. Understanding and maintaining water and food security depend on managing the interaction between water, ecosystems, and the services they provide with agriculture. Through the more widespread adoption of ecosystem-based solutions, there are opportunities to move away from viewing the agriculture-ecosystem-water interface as one of conflict and trade-offs, and toward simultaneously achieving both increases in sustainable food production and improvements in the delivery of other ecosystem benefits by agriculture. Similar to the elements in feed, livestock water as an ecosystem service must satisfy the animal's nutritional requirements.

Animal health and production depend on a reliable supply of clean water. Numerous elements, including size, production, food, and environmental circumstances, have an impact on the water needs of livestock [32]. Dehydration, which can be lethal to animals, can be caused by restricted access to or decreased water consumption. For the health and productivity of livestock, it is essential to provide them with enough water. The majority of domestic livestock species die at a 10% body water loss. At maturity, water makes up between 50% and 81% of an animal's total body weight and more than 98% of all the molecules in the body [33]. [34] acknowledged that water is essential for digestion, development, reproduction, lactation, controlling body temperature, lubricating joints, and maintaining good eye sight. The amount of water needed by livestock varies greatly depending on the species. Age, rate of gain, pregnancy, lactation, activity, type of diet, feed intake, and environmental temperature are just a few of the variables that affect water consumption. Wells, fountains, surface water, and moisture in feedstuffs are some of the sources of water used by livestock to meet their needs.

[35] noted that dehydration or a lack of water can be caused by difficult access to or availability of water, ambient temperatures, stress, and disease. Lethargy, skin tightness, weight loss, and dryness of mucous membranes and eyes are typical symptoms of dehydration. The amount of water ingested is typically the most crucial factor when considering it as a nutrient. More often than an induced mineral imbalance, pollutants will reduce water consumption. Higher concentrations of some salts and other elements in water can harm and kill animals or impair their growth and productivity. However, many species can ingest a wide variety of various types of water and live thanks to their physiological plasticity.

Depending on the species, breed, ambient temperature, water quality, amount of feed consumed, amount of water in the feed, animal activity, pregnancy, and lactation, livestock consume roughly 25 to 50 l/TLU each day [36]. It is also necessary to replenish water lost through urination and feces by drinking or using the water content of feed. When the ambient temperature is between 150°C and 270°C, the amount of water consumed varies from approximately 3.6 to 8.5 l/kg of feed. Lactating cows consume additional fluids, up to 85 liters per day for high producers. Lack of water lowers feed intake, which in turn limits weight gain, milk production, and LWP. Production will increase in mixed crop-livestock systems in SSA when piped water is given to the farm, even though it is expensive [37].

Water for livestock watering can be sourced by taking raw water out of ponds, streams, or other natural water sources. Making the most of rainwater and recycling water whenever feasible helps to cut costs because mains water is expensive. Where there are no alternatives to livestock using natural surface water sources for drinking, there are rising worries about the harm to the ecosystem as well as the impact on animal health. It is not always practical to allow livestock to graze close to natural water sources, and there are growing worries that this could occasionally result in issues. Giving animals access to readily available surface water is frequently no longer sufficient as herd sizes increase and contemporary animal husbandry becomes increasingly mechanized.

The amount of water utilized for drinking and other purposes during an animal's lifetime is taken into account when calculating the virtual water content of live animals. The term "virtual water content" was created since the amount of water in a finished good is far lower than the amount of water utilized to make it [38]. Poor management of livestock and water in pastoral settings sometimes results in contaminated or sediment-filled watering facilities, overgrazing of nearby pastures, danger to residential water consumption, and risk to the health of both humans and animals. However, the ability to distribute animals, especially cattle, more efficiently so they can eat forages without overgrazing the land is likely the most significant benefit of supplying drinking water in grazing fields. For instance, a case study in [39] showed that 65% of the available pasture was farther than 730 m from water and that 77% of grazing occurred within 366 m of water

In Africa, there are frequently too few and poorly dispersed and managed livestock watering stations. Some locations have dry seasons when livestock must travel for hours to seek drinking holes, using up a lot of energy in the process. According to [40]'s research in Sudan, attaining an ideal geographical distribution of sites for livestock and drinking water will significantly boost LWP and lessen the degradation of land and water.

4. Livestock water productivity for food security

Livestock Water Productivity (LWP) is defined as the ratio of beneficial outputs and services provided by livestock to the amount of water used to produce these outputs and services, according to [41] and [42]. LWP is based on the principles of water accounting. For only the production periods, the milk's water productivity is estimated. Water required in the manufacture of feed and fodder, drinking water, and water used for sanitization, such as cleaning and washing of animals and sheds, are all taken into account when determining an animal's water needs. Water productivity in the production of eggs is measured by the number of eggs produced for each unit of water supplied to the batch of poultry birds.

In semi-arid regions, both LWP and animal output are low. Due to increased consumer demand for animal products, global water limitations, and water competition, there is an urgent need to increase livestock production without further depleting water supplies and while safeguarding the environment. Enhanced ascertaining livestock water productivity in livestock production systems can help the environment and people's quality of life. The idea of livestock water productivity is well-established in the world of agriculture, where it has been intensively discussed for many years [43]. However, there are knowledge gaps and a dearth of references in many domains as a result of the idea's recent development [44]. Future population growth, shifting consumption patterns, urbanization, and climate change are all expected to increase competition for freshwater resources due to the demand for food production (crops and livestock). To address the future water crisis, it is crucial to investigate how to increase water productivity, particularly in food and livestock systems.

The link between livestock and water has recently received more attention, as seen by the rise in publications on this subject [45, 46, 47]. To increase livestock water production, [44] contend that a deeper comprehension of the relationships between cattle and water is still required. The use of technology to boost livestock water productivity (LWP) presupposes three intervention categories related to feed, water, and animal management using a framework for mixed crop-livestock systems. According to [48], although daily drinking water intake is commonly thought of as a livestock's water demand, daily feed production really requires about 100 times as much water as daily drinking water consumption.

Some feed-related actions for improving LWP include making intelligent feed type selections, improving feed quality, increasing feed water productivity, and using grazing management methods. Managing watering sites, conserving water, and incorporating animal production into irrigation planning are all parts of water management for higher LWP. Evidence demonstrates that successful uptake of treatments is possible when institutions, policy, and gender are considered. Critical research and development gaps must be resolved in the areas of methods for measuring water production at different sizes and fostering collaboration among agricultural sectors. Increasing the water-use efficiency of feed production and utilization will increase livestock water productivity (LWP). Improved household nutrition, food security, and livelihoods are all benefits of increased LWP, which also protects the environment's resilience and turns back land degradation [44]. The innovations necessary for LWP advances and the farming systems where they occur are influenced by biophysical and sociopolitical-economic factors [45]. Therefore, technical interventions will only be put into action if institutional, cultural, and financial conditions are met.

It is unclear how much water different feed types use, as well as how management practices and agro-ecological zones affect water output. Enhancing livestock water productivity (LWP) in mixed crop-livestock systems is essential for increasing overall production [49]. The water needed to create the livestock outputs was determined by the same authors using the amount of water required to make the feed. According to [50], technical interventions for greater livestock water productivity (LWP) postulate three intervention categories relating to feed, water, and animal management. They do this by using a framework for mixed crop-livestock systems. Some feed-related actions for improving LWP include making intelligent feed type selections, improving feed quality, increasing feed water productivity, and using grazing management methods. Managing watering sites, conserving water, and incorporating animal production into irrigation planning are all parts of water management for higher LWP. When compared to farming systems without livestock, those with integrated animal agriculture that are fed on crop byproducts or graze rangelands frequently have higher water productivity [51].

Diversifying livestock production is one of the primary tactics for enhancing smallholder production. Water production overall will increase if livestock sector water use is reduced. The primary areas of water use in the livestock sector are primarily feed and sanitation. Drinking water only has a very small impact on water usage. Along with the production of meat and milk, animal waste is an important factor in LWP. Several researchers have made various recommendations on LWP [44, 50, 52]. These include of livestock animal husbandry management practices such as use of adapted breeds for production, disease tolerance and control, etc. Strategies for overall water management include integrating animal production with agricultural irrigation systems and strategically placing and regularly checking watering sites has work well in smallholder farming setup. Optimal use of multipurpose feed, timber and forest products, proper crop and cultivar selection for livestock, more suited grazing and agronomic management, etc. enhancing the nutritional value of feed and using crop leftovers or agricultural byproducts as livestock feed is a possible strategy to improve LWP.

Water needed to manufacture animal feed is the main resource needed for the production of animals. In theory, animals can eat a variety of plant materials, such as grains, grasses, fodder trees, crop by-products, and crop leftovers. Selecting the most water-productive feed sources that yield adequate feed to suit animal needs is a crucial tactic for boosting LWP. In conclusion, simultaneous development of crop and animal production will have a significant positive impact on livestock water productivity, which is calculated as the output of agriculture and livestock per unit of water. A really thorough estimate of livestock water productivity must take into account the less obvious and quantifiable items that are produced by cattle, including draught power, manure, and a variety of social functions [41, 50, 47].

By raising the proportion of feed energy utilized for production to maintenance, LWP may rise. The LWP technique quantifies benefits in terms of money, therefore it stands to reason that market conditions have an impact on how efficiently water is turned into useful animal outputs. Because of this, LWP may be higher when livestock keepers have simple access to markets, valuable, high-quality, disease-free products, and the ability to boost value at the farm gate by, for instance, changing liquid milk into butter or cheese. However, caution should be exercised when relying exclusively on LWP's total economic value because doing so hinders the conversion of animal products into the various nutrients essential for human nourishment.

It is important to identify the feed supply options for the agricultural or grazing system that will result in the highest LWP. Grazing on vegetation with little value for preserving the environment's health or for satisfying other human needs may offer a source of feed with a low water cost. The worst-case scenario is that importing feed enables animal production without the water costs connected with feed produced locally. Livestock keepers must continue to operate profitable businesses because a high LWP does not always reflect a high level of production. A big chunk of Africa's shortage of feed resources means that much of the food consumed is for maintenance, leaving little for production.

5. Climate change and livestock water use: implications for animal productivity and food security

It is now common knowledge that a changing climate will have an impact on the availability of water resources and the worldwide hydrological cycle [53]. Climate change, livestock water availability, small-scale animal production, and food security in Africa are all intricately linked. For agriculture, especially animal production, water is a necessity. Global climate change is currently putting strain on animal production because of its effects on forage quality and water availability. There is a compelling need for more knowledge on the nature of livestock-water interactions given the growing concern around the world that access to agricultural water would limit food production and that livestock farming uses and uses too much water.

Climate change poses a threat to agricultural productivity, especially animal production in regions with a food crisis, particularly in Africa. The way of life of small-scale animal producers has been negatively impacted by a range of climate-driven extremes, including drought, heat waves, irregular and heavy rainfall patterns, storms, floods, and emerging insect pests. This has had an impact on agriculture food systems. Despite the unpredictability of climatic patterns, projections for the future climate revealed a marked rise in temperature and erratic, severe rainfall that would harm food production.

[52] stated that increasing food and water demands, climate change, and environmental degradation all contribute to the continent of Africa's water scarcity issues. Raising livestock is a major source of income for smallholder farmers in Africa, but it also consumes a lot of water, and as the market for animal products expands, so does this consumption. Furthermore, animal farming's present-day low returns restrict its capacity to assist rural livelihoods, particularly food security. Small-scale animal husbandry faces significant challenges, particularly in arid and semiarid countries where limited freshwater supplies and climatic change have an impact on animal productivity and food security. Global warming and a decline in rainfall are indicators of climate change, which may undermine the quality of livestock water and affect animal performance.

Increased precipitation due to climate change may result in larger peak runoffs and less groundwater recharge. Longer dry periods may result in decreased river flow and groundwater recharge, which would affect water availability, agriculture, and drinking water supplies. Ineffective animal management practices frequently result in significant, widespread water depletion, degradation, and contamination. Numerous environmental groups in wealthy countries are growing more concerned that livestock production is a big contributor to the contamination of land and water.

Climate change will have a considerable impact on the quantity and quality of water available to small-scale animal agriculture, which mainly relies on rainwater as a production component. Grazing livestock and pasture growth can have both good and negative effects on water quality, according to [54]. Compared to traditionally produced crops, good management approaches for forage production prevent soil surface erosion. Through erosion and sediment movement into surface waters, nutrients from animal wastes including urine and feces, fertility practices used to produce high-quality pasture, and diseases from the wastes, grazing animals and pasture production can have a negative impact on water quality.

Climate change will draw attention to the close relationship between water quantity and quality. As the world's population grows, the requirement for food will also increase, which will exacerbate the issue. Water is necessary for animals and birds to drink, and the production of feed supplies is closely linked to the need for rain-fed water, which has been impacted by unpredictable seasonal phenomena as a result of climate change. Water management is becoming one of the key geostrategic challenges, along with energy access, as climate change is anticipated to exacerbate current water supply and demand imbalances. Increased water temperature due to global warming may cause harmful cyanobacterial blooms, algal blooms, and a decline in biodiversity [55].

Water quality for drinking in rivers and lakes will therefore be impaired. Water demand for livestock and crops can be directly impacted by climate change. Water is the major component of animals' and birds' bodies, comprising 50%–80% of their live weight [56]. Water from drinking sources, water in feed, and metabolic water created by nutrient oxidation all help livestock meet their needs for water. According to [57] report animals can lose water from the body via respiration, evaporation, excrement, and urination. The forage's water content varies as well; it stays at 90% throughout the growth season and drops to 15% during the dry season. Grain, concentrate, and dry feed all contain 5-12% water. Up to 5–15% of the body's water needs can be met by metabolic water. Only 0.6% of the world's freshwater is needed for human consumption and livestock needs.

A framework should have proffered for improving livestock water productivity index, especially for small scale animal agriculture that is predominantly mixed crop-livestock production systems. This will facilitate ways to enhance crucial livestock-water interactions. Including livestock and water resources in planning, development, and management could help decrease poverty, boost food production, and lessen pressure on the environment, including the limited water resources while sustaining food security. A holistic approach that take into account combined institutional, policy, and technology initiatives can be employed to address climate change induced water scarcity. Choosing feeds that use the least amount of water, improving land and animal management to preserve water, increasing animal output using tried-and-true methods from the animal sciences, and thoughtfully providing drinking water in the right places at the right times are some of the suggested solutions to this problem of water use. To accomplish integrated livestock-water development, experts in the domains of water and animal sciences will need to rethink and manage water in new ways. Keeping water's quality under control is more challenging when there is less of it available. Understanding the sensitivity of water resources to climate change is crucial for promoting the development of animal production adaption techniques, which in turn enhance food security.

6. Water requirements of different domesticated animal and avian species

A necessary but sometimes ignored nutrient is water. The primary determinants of an animal's water intake are feed intake [58], the amount of dry matter (DM) in the diet [59], dry matter intake (DMI) [60,61,62], the status of the animal's production (Castle and Thomas, 1975[63]; Meyer et al., 2004) [64], body weight [62. 64]. Varying domesticated animal and avian species have different water needs. Water availability constraints may lead to poor animal nutrition because of the close association between water intake and the consumption of roughages [65], albeit a slight restriction does not seem to be damaging in reality. However, variations in water utilization efficiency between breeds have been noted [66].

The body needs water for a number of physiological functions, including solvents for biological fluids, temperature regulation, proper digestion, and absorption of food. Therefore, cattle performance and productivity might be severely limited by a suboptimal intake [67]. In addition, water is essential for controlling an animal's internal body temperature as a reaction to external temperature changes and other factors, such as oxen's draft work. The digestion and absorption of nutrients including carbs, proteins, and lipids depend heavily on water. Water aids in the release of some hazardous metabolic products, such as urea, and aids in the exhalation of bodily waste after digestion. Therefore, a shortage of water will affect body physiology more abruptly and severely than a lack of other nutrients.

Water stress impairs energy production, and attempts to sustain energy requirements typically lead to the mobilization of fat from adipose tissues [68]. In a related study, [69] noted that Xhosa goats subjected to water restrictions of 70% and 50% of ad libitum intake for 75 days experienced an increasing loss of body condition. The current study's fall in body condition scores and body weight demonstrated the inverse relationship between the length of time without water and body condition scores and body weight.

Through saliva, sweat, breathing, and other critical mechanisms employed by the animal to lessen the heat burden, water also aids in controlling body temperature [70]. Additionally, it is better to mix medications with feed than to add them to drinking water when it comes to disease prevention and management. This facilitates quick and simple medication administration while also guaranteeing adequate drug intake. Animals that are ill typically cease eating, although they typically continue to drink. Water plays a significant function in the prevention of abortions and other reproductive issues during pregnancy and makes up a large amount of the placenta overall.

The pH balance in an animal's body can be regulated by drinking enough water [71]. They share all the same bodily functions with us, which must be maintained in a healthy state. They risk becoming seriously ill or perhaps passing away if the pH balance in their body is not supported by enough water. Since water quality also influences how much is used, it should be taken into account. For instance, if the water is tainted with hazardous compounds, has a high mineral content, and tastes salty or bitter, water consumption will be minimal. These toxins can lower water intake and contribute to poor water quality, which could decrease feed intake and diminish production.

During rehydration, water-stressed Bedouin goats have also been seen to consume more water [72]. Intake of both water and feed is favorably connected. This is because a water medium is necessary for efficient digestion, passage through the system, and food absorption [73, 74]. A much greater average daily water intake may be the cause of the observed increase in average daily feed intake in the 48 h water-deprived groups compared to the 24 h and 0 h groups. Because the grazing materials (grass) are drier and tougher, it is more difficult for animals to bite, chew, and digest them; as a result, their bodies will need more water to speed up the process. Additionally, water serves as a conduit for the movement of blood and nutrients to all human tissues and organs, as well as the elimination of waste products like urine and feces (excretion). This is clear, for instance, during summer grazing, when the animals consume more grain and digest it more quickly, yet consume less water each day. The contrary is true during the dry season, when there is a higher daily requirement for water and a lower or slower rate of feed consumption and digestion. Table 1 shows the water requirement of classes of animals at different stages of production and physiological status.

Table 1. Water requirement of classes of animals at different stages of production and physiological status.

Class of cattle	Amount of water (litres/day
Beef cow, dry	15-40
Beef cow, lactating	40-70
Fattening cattle	25-75
Growing cattle	15-50
Cow with calf	50
Dairy cow in milk	68-155
Yearling	24-36
Two year old	36-50
Ewes with lamb	9-10.5
Pregnant ewe/ram	4-6.5
Lactating dairy ewe	9.4-11.4
Feeder lamb	3.6-5.2

A livestock and avian watering program's objective is to supply water in quantities that, under the prevailing environmental circumstances, would be greater than voluntary intake in order to ensure adequate water availability. Water of good quality should always be available for free consumption. Water is essential for life, thus for animals to be as productive as possible, they should have unrestricted access to clean water that is sufficient to meet their daily needs. Table 1 provides information on water requirement of classes of animals at different stages of production and physiological status.

7. Livestock water from a gendered perspective and its effects on animal productivity and food security

The 2030 Agenda for Sustainable Development's global commitments make achieving gender equality in the water sector imperative) [75]. Livestock water is no exception to the widespread and persistent gender imbalances that have a significant impact on attempts to achieve sustainable development everywhere. In many cases, gender determines a person's potential through defining their social roles, duties, and opportunities. Women and men consequently possess diverse information, skills, opportunities, and needs. The needs, access, usage, and advantages of this essential resource are shaped by gender, which in turn affects how people relate to it. Gender equality in livestock water systems and management will lead to more productive, sustainable small-scale animal husbandry that will improve dietary provision and food security for rural households, communities, and future generations. In the smallholder agricultural sector, livestock production is gender-specific, and animals not only provide a means of subsistence for hundreds of millions of rural people but also act as a powerful access point for battered women. For women to fully contribute to reducing poverty and malnutrition and expanding economic possibilities for everyone, especially for women and girls, reducing gender inequities in water consumption generally is crucial. Gender relationships vary regionally and are dynamic. Systems for raising animals vary and evolve over time [76]. Gender relations are affected by rising human population densities because they lead to more intensive production, present new market opportunities, but also impose shifts in labor costs between men and women. [77] in both male- and female-headed homes, the workload for women rises but output control and decision-making authority decline [42]. Therefore, in order to provide effective recommendations and provide entry points for technological solutions, efforts to improve the LWP in crop-livestock systems need to have an awareness of particular gender relations and dynamics [45,78]

Among the Third Millennium Development Goals is the aspect of gender equality and women's empowerment, and it is thought to be a crucial element of sustained economic growth, poverty reduction, and food security. The ability of African countries, and small-scale animal agriculture is no exception, to translate gender policies into practical, implementable initiatives continues to be a problem. Rural livelihoods continue to be characterized by significant gender disparity, particularly in the rearing of livestock. Africa is characterized by gender differentials in the social, cultural, and economic spheres and situations of women because of dominating patriarchal systems that maintain women in a subordinate position. Gender issues must be addressed, particularly in the field of working with water, which is frequently a task performed by women and girls. These issues include the role played by women in innovation processes as well as the effects of changes in water access and use on women's workloads and decision-making.

The roles of men and women in livestock-water differ among production systems. For instance, in pastoral systems, males and kids, especially boys, frequently herd and water animals, whereas girls and women are in charge of the young and sick animals [76]. Knowing where there is water to graze and trek depends heavily on a man's understanding of water availability. Herding and watering within constrained geographic boundaries are additional labor-intensive tasks in agro-pastoral and mixed agricultural systems that are primarily performed by children. Women and children typically collect drinking water from local sources for stall-fed cattle in urban and peri-urban setups. Additionally, these positions differ between countries, ethnic groupings, and religions. Therefore, initiatives aimed at enhancing the management of livestock water resources and expanding access to water should make the most of the crucial responsibilities that women already play in the management of the water resources that power animal production for food security.

Gender needs to get more consideration in interventions designed to increase LWP [79]. The bulk (70%) of rural impoverished people are women [80]. Due to their traditionally gender-specific roles in livelihood activities, such as female care for home needs and tiny stock, women have had limited access to information, technologies, inputs, and markets. Men, however, are in charge of huge corporations and stocks. De jure female headed (single or widowed female) households are the most economically vulnerable and disenfranchised members of communities [81]. Men are looking for money off the farm in greater numbers, which increases the participation of women to agricultural activities. As a result, women take on more responsibility for agricultural output, including the selling of livestock products (feminization of agriculture) [82]. Water usage and "users" are frequently categorized based on gender. The roles of men and women are complicated in reality. Thus, a comprehensive examination of gender is necessary, taking into account both the general environment and the various dynamics that a given project will function in.

Although gender is increasingly mentioned as a top priority in policy documents for managing water resources [78], the water sector pays little attention to the potential for negotiating gendered roles at the household level, particularly in terms of livestock water usage. Women traditionally control household water decisions in many poor nations. According to [83] communities get higher economic and environmental benefits when women are actively involved in managing water resources, and this may translate to effect water use and improved agricultural productivity. Women are essential to ensuring more sustainable access to this limited resource as the global population is increasing and the effects of climate change become more pronounced impacting on water resources. The ease of access to water source(s) in various production systems may significantly affect the gender division of labor for livestock-water interactions, the amount of water used, and its effectiveness in livestock production when combined with competing demands for household members' labor for other uses. This indirectly affects the labor and welfare of many household members, particularly women and children and this has implications for animal productivity and food security.

Despite a minority of men being members, [84] noticed that women were not allowed to join organizations for livestock producers and water users. It has been asserted that the community misses a big potential to significantly boost LWP and animal output by not utilizing the already-developed capacity of women. Women's lives are changed when water is easily accessible. Every day, women and girls spend 200 million hours collecting water across the world. This relationship between women and water may seem simple, but for many people, it is deeply personal. In rural areas, water is essential for women and girls' time, health, and safety. Future attempts to enhance livelihoods through livestock development will focus heavily on increasing the participation of women in decision-making, which may improve animal output and promote food security.

Worldwide initiatives stress the necessity of taking action to include women more fully in development overall and to closely integrate them in the management of natural resources. Through participatory strategies that acknowledge the essential role of women, it will be possible to increase the participation of the users in the management of water resources. The new agreement states that gender sensitive methods should focus on the best means of ensuring women's increased participation in the water sector. Furthermore, men and gendered connections are conspicuously lacking from this vision of water resource management; policy pronouncements and project approaches continue to place a significant emphasis on women's participation rather than a more comprehensive gendered approach.

While there have been some commendable strides made in the direction of integrating complex gender approaches to water [85, 86, 87, 88], the current policies and practices of many governments and development organizations can be criticized on three different fronts. First off, such methods continue to favor a specific sector; Second, methods for planning water projects and involving stakeholders are still very technical and frequently based on a model for infrastructure development; Thirdly, most policy methods don't establish a convincing connection between the particular participant and the social environment in which they function. The necessity to integrate studies of water resource management at a number of levels, including that of the gendered individual, the family, and the community, then presents key issues of concern.

Gender and food security are closely related because women are typically the primary food providers for households. Household farming offers a safety net for the family to smallholder farmers, where women frequently maintain livestock in addition to other agricultural activities, with a lot of help from household water supplies. The improvement of dependable water supply could have a significant positive impact on household food security through improve livestock production. Water is frequently used by women for a variety of other -home based activities. Therefore, planners must take this into account and offer water access that matches the variety of uses that women make of it.

Despite the language of inclusion, men's and women's individual differences in worth are rarely taken into account. Assessing how water affects people's livelihoods and taking into account user behavior, supplier definitions, and the gendered dynamics of family water decision-making would be a better way to value water. Finally, without addressing or examining this paradox, a technocratic approach to water resource management views "culture" as both a promise and a hindrance. As a result, a lot of project literature notes that women's participation was limited by prevailing patriarchal socio-cultural norms [89], while also pointing out that there were a lot of challenging managerial decisions to make. The implementation of policies and programs to address water insecurity must take into account gender norms and other factors that contribute to inequality. Too frequently, gender-neutral policies and programs on agricultural water management fail to take into account the particular needs and experiences of women.

Women make significant contributions to livestock farming, particularly in the area of livestock watering, as well as to the livelihoods, welfare, and food security of families and communities. However, these contributions are frequently ignored, unacknowledged, and generally devalued. Along with this, women's contributions to agriculture's management of both productive and non-productive water are frequently ignored and understudied. Thus, there is a need for a paradigm shift in gender analysis of agricultural water use that focuses primarily on productive agricultural resources, including water, in order to inform future programs for more effective, equitable, and gender-responsive animal production. This paradigm shift aims to shed light on the different contributions and benefits of women and men in relation to agricultural roles, responsibilities, and resources.

Gender analysis of water resource management that considers both social and infrastructure-related issues, accounts for both group and individual activities, and acknowledges complexity, diversity, and change on many scales is called for. The review makes several different attempts to do this, focusing on the interplay between individual agency and collective action with social structure as well as the crucial role of formal and informal institutions in influencing both public and private activities. An attempt has been made to developed water policies relating to inclusion and gender. Nevertheless, there is still a gap between policy and practice because neither is consistently backed by adequate finance or well-defined action plans.

8. Animal adaptation to climate induced water stress and productivity in animal production

Different species and varieties of ruminant livestock, however, have developed physiological mechanisms to deal with and reduce negative consequences from this stress factor and others [90]. Livestock suffers from inadequate water intake. While small ruminants are more tolerant to below-optimal water consumption than other livestock species, different breeds have different levels of toleration. Climate change is predicted to expand the areas where there are limited supplies of water suitable for animal consumption as well as enhance availability in areas where there are currently insufficient supplies. According to [91], neither species' body mass nor the ratio of water intake to dry matter intake changed when water was restricted for 21 or 42 hours per day. D2O was also used to confirm that there were no species-specific changes in their WIs. However, in both the control and treatment groups, sheep exhibited greater respiratory rates and rectal temperatures than goats.

Animals have the capacity to endure a mild water deficit by triggering a number of physiological and behavioral mechanisms. Animals raised in extensive animal production systems already face tremendous demands to adapt due to the current high rate of climate change. Our long-term objective in animal production under climate-induced stresses is to provide the knowledge and tools required to increase the resilience of animal production systems to environmental stressors. The main premise is that substantial variation exists across and within the existing local animal genetic resource populations, and that genetics plays a significant role in adaptation to environmental stressors.

Compared to other mammals, goats, especially types acclimated to dry environments, have a more effective renal system and are able to switch between drinking water and water consumed with food [92]. According to [93], goats in temperate regions require 107 g/kg BW0.75 of water for maintenance. The amount of water used by goats in their late pregnancy would increase by 40–50%, reaching around 165 g/kg BW0.75 for goats producing 148 g milk/kg BW0.75 at 10 weeks following parturition. When compared to other domestic ruminant species, goats are less vulnerable to environmental stress because they can conserve water, sweat more, have a lower basal metabolic rate, breathe more quickly, have higher skin temperatures, and maintain a consistent heart rate and cardiac output [[94]. In a similar study [95] found out that goats are more resilient to a variety of conditions than sheep and cattle, including heat stress, a shortage of food and water, and difficulties associated with the bush. When it comes to coping with seasonal biotopes, experiences of water and feed scarcity, and structural features that allow for behavioral adaptation, goats clearly have an advantage over sheep and cattle. Accordingly, goats are anticipated to be the species of the future with the greatest capacity to fend off the dreadful effects of climate change that are expected to manifest by the end of this century, as well as to significantly contribute to maintaining food security to meet the demands of the growing human population.

Throughout evolution, various animal species have developed adaptations to a range of environmental stresses. Animal species that cannot change with climate change go extinct and become petrified. Adaptation is an organism's capacity to adjust to varying environmental circumstances. Animal adaptation primarily involves the animal's ability to alter in morphology, behavior, and genetics. These may develop over several generations as a result of animals' gradual adaptations to environmental obstacles. [96] states that farm animal adapts its phenotypic and physiological characteristics in response to its surroundings. Physical response, morphological response, blood biochemical response, neuroendocrine response, molecular and cellular response, metabolic response, and behavioral response are among these characters that are most significant.

[[97] noted that most of the year, livestock in arid and semiarid regions struggle with a lack of water supply. Animals must therefore use adaptation mechanisms to get around water shortages at various physiological phases. The animals display a variety of adaptations to deal with the water shortage. Reduced body weight, decreased faecal moisture, decreased plasma and urine volume, and decreased feed intake are some of these mechanisms. Haemoglobin levels are higher, blood cholesterol and urea levels are higher, protein concentrations are lower, and sodium and potassium concentrations are higher, among other blood biochemical alterations. In livestock, the endocrine changes include higher cortisol levels and lower insulin, T3, T4, and leptin concentrations. Furthermore, water restriction in the rumen is crucial for preserving homeostasis.

[98] observed that there were no changes in the sheep's body weight or rectal temperature after exposure to the water stress. However, water stress had an impact on respiration frequency, which decreased in control and water-deprived animals from 23.3 to 13.3 respirations per minute, respectively. Additionally, there was evidence of hemo-concentration in response to imposed water stress (levels of hemoglobin increased from 9.2 to 13.1 g L1 and hematocrits from 27.6 to 39.3% in the control group and animals restricted to water once every 6 days), as well as a decrease in lymphocytes (from 63 to 43%) and an increase in neutrophils (from approximately 38 to 54%) and leukocytes (from approximately 38 to 96%). (from 3133 to 4933 per mm3). This is an indication that water stress compromised the health status on animals.

Although the breed effect may be important in adapting to water stress, [99] noted that the following are typically observed common responses: decrease in feed intake and weight loss, increase in evaporative cooling through panting, production of a small volume of highly concentrated urine, haemoconcentration, high blood osmolality, and immunosuppression. As seen in heat-stressed sheep husbandries, a prolonged water deficit may have an impact on lamb birth weight and survival as well as reduce milk production, especially in non-adapted breeds, which could result in significant financial losses. New methods for reducing stress are also provided, like vitamin C supplementation.

Little body temperature increase was also seen during the hottest part of the day, followed by body cooling by conduction and radiation at night. Because of the ability to withstand this temperature increase, evaporative cooling requires less water [100]. Water restriction has an impact on drinking behavior of animals. In sheep and goats that aren’t getting enough water have a tendency to consume a lot of water all at once when they are watered. Goats exhibit this ability more clearly than sheep do. In adapted breeds, the amount of urine and feces that are wet decreased when water is inadequate. Renal urea retention raised blood urea concentration in a dehydrated state [68].

The length of Henle's loops, which are situated in the kidney's medulla, causes the production of the more concentrated urine [101]. In comparison to domestic breeds, well-adapted breeds have thicker medullas that can produce more concentrated urine. The ability of different sheep breeds to survive water shortages varies; the desert bighorn sheep (Ovis canadensis nelsoni) can go up to 15 days without drinking [102], whereas the Barki sheep in Egypt could only go for three days without drinking [103]. Between these two extremes are reports on other breeds, such the Awassi [99], Yankasa [104], Merino [105], and Barbarine sheep [106]. In animals that have been acclimated to water shortage, the rumen also contributes significantly to maintaining homeostasis. Because of its substantial size, it serves as a significant water reservoir.

Despite the fact that animals have numerous and varied adaptations, there are limits to animal adaptability. They enable species to endure, but ultimately something will appear to take their place. This is because their capacity for adaptation is limited. However, due to the overwhelming influence that people have on the earth, many adaptations are not being permitted to occur naturally. Under climate change scenarios, adaptation measures such as the use of locally adapted animal genetic resources may increase the total productivity and profitability of the animal production systems.

9. Breeding for adaptability to address climate change induced livestock water stress in small scale animal agriculture

Due to deception about the value of the continent's own animal genetic resources, Africa has significantly paid a have price with perpetual food insecurity. To ensure enhanced smallholder livestock production and food security in the face of present climate-induced water stress, a long-term strategy that incorporates AAGnR must be created. The industrialized world is actively imparting adaptive features of their highly genetically animal breeds for the production of meat, dairy, and eggs in order to decrease the effects of pressures brought on by climate change. If Africa had been able to develop and promote its own local animal genetic resources to combat the effects of climate change, it would not be suffering from ongoing food insecurity. The effects of climate on the food systems in Africa would have been less severe.

A long-term solution to the water stress brought on by climate change in small-scale animal agriculture could be achieved through animal breeding for adaptability. An animal's genetic makeup controls its fitness and adaptability, which also affects how well-adapted it is to adverse climatic conditions including heat, drought, pests, and illnesses [99]. Under climate change scenarios, adaption strategies like the use of genetic resources for animals that have been regionally acclimated may boost the overall productivity and financial success of the animal production systems. The intrinsic genetic variety, which interacts with environmental constraints to produce phenotypic variation, is the main factor in adaptation, as assessed by survival and reproduction [106]. An animal population's hereditary features that aid in survival are referred to as genetic adaptation. Small-scale animal agriculture has been conducted for generations under difficult environmental conditions. Breeds that have evolved to survive in the harsh climate have a variety of survival-enhancing traits.

[107] claims that competition for the same resources occurs both within and across species, leading to morphological decisions that support population survival. Natural selection ensures the survival and successful reproduction of animals that are genetically adapted to a particular ecosystem. One of the unique adaption qualities that local animal genetic resources possess that enables them to flourish and produce under difficult conditions is their tolerance to water stress. These characteristics developed in tough,

semi-arid, tropical agroecological areas. When compared to exotic animal genetic resources of cattle like the Bos Taurus, Indian-derived cattle breeds like the Bos indicus do better in hot climates because of their ability to thrive in harsh settings.

In a situation that is getting more difficult, raising the appropriate breeds or species is necessary to preserve animal production [108], particularly in areas where climate change-related water stress is prominent. Animals with the ability to select high-quality fodder and maintain a somewhat comparable basal diet quality from season to season would substantially reduce their consumption when forage biomass and quality are low during exceptionally dry seasons [109]. Additionally, it has been observed that periods of high ambient temperature and poor feed quality and availability are associated with an increased frequency of water shortages. The results of these three limitations consequently frequently clash with one another.

According to [65], ruminant breeds that have acclimated to dry climates are more able than non-desert breeds to endure environmental stresses like water stress. Furthermore [110], demonstrated that a lack of water affects animals' physiological balance, resulting in weight loss, decreased reproductive rates, and lowered disease resistance. Small ruminants can therefore last up to a week without much or any water in hot, dry, and semi-arid regions. The ability of the AnGR to adjust to various climate-induced stressors, such as water scarcity during irregular times, depends in large part on the preservation of the region's animal genetic diversity. The capacity of the world's systems for raising crops and cattle for food to adapt will be under great pressure from future climate change [111]. The main challenge will be to keep livestock systems adaptable while ensuring their continued productivity and efficiency. This is expected to be a difficult task because of the resource limitations of Africa's food production systems.

To adapt to climate change, probably won't be enough to use just one technique. It is certain that adjustments will be required for animal housing and buildings, animal breeding, nutrition, and animal healthcare. It will also be crucial to manipulate animal genetics through breeding (across and within species). To prepare for these changes, a significant amount of concentrated research will be required, and genomics will be crucial for the genetic adjustments undertaken. Although many animal breeds have been genetically defined to date, it is questionable whether these results are pertinent to the study of adaptability. The importance of farm animals raised in hard conditions, such as dry and semi-arid regions, may be at its maximum right now for adjusting to climate change. The primary focus of earlier studies was on the genetic resources of exotic animals that have undergone rapid genetic improvement in industrialized countries where temperature control is routinely utilized. The study of adaptation requires the use of a "holistic approach," which includes thorough descriptions of the production system, socioeconomic data [112], indigenous knowledge about managing the breed in its environment, as well as geographic coordinates to incorporate climatic data and soil, vegetation, and animal populations.

The effects of climate change are currently being addressed by improved animal production systems in developed countries using what is referred to as a "adaptive breeding approach" in order to regain resilience and adaptability traits that have been lost in improved breeds over the course of decades. These breeding methods encourage resilience and adaptation to boost the output of cattle, dairy products, and poultry. This shows that recently discovered adaptive qualities that may be advantageous for less intensive smallholder agriculture are mostly derived from genetic animal resources in Africa; in actuality, this is a lesson for Africa to avoid being deceived. Africa already has a candidate to address the problem of food security and the long-term effects of climate change.

Climate change is affecting animal farming, notably in terms of livestock productivity. How the animal agriculture sector responds to changes in rainfall patterns, the frequency of extreme weather events, and the availability of freshwater for animal hydration will determine how well it can adapt to climate change and grow. The dangers and opportunities of a changing climate have not been properly addressed in order to assist resilience and adaptation in the small-scale animal husbandry industry. This is especially true when it comes to how climate change affects livestock's access to water and how that affects animal performance and food security. Even with the ongoing changes brought on by climate change, this remains true.

10. Climate-smart livestock water technologies for sustainable small scale animal agriculture

Small-scale farmers have been employing new animal production management practices ever since in an effort to adapt to their surroundings and seize opportunities. As water becomes more limited, it is imperative to enhance local innovation processes in order to maximize water productivity in crop-livestock systems. Endogenous development and local adaptation of outside interventions fall under this category. In order to adapt to climate change and variability, water-smart agricultural technologies combine traditional and contemporary techniques, technology, and services that are appropriate for a specific site [113]. With careful planning and implementation, water-smart technologies that are specific to a region offer a great deal of promise to lessen the impact of climate change on water supply.

There are numerous factors that influence the adoption of smart water technologies, including the socioeconomic mix of farmers, the biophysical environment of a particular place, and the qualities of new technology [114]. Major challenges to scaling up water-smart technologies in various agro-ecological zones include identifying, prioritizing, and promoting workable solutions while taking into consideration regional climate risks and technology demand.

By combining region-specific approaches for both supply and demand side management, problems of livestock water scarcity might be adequately handled. This would require the adoption of smart livestock water management strategies and contemporary livestock technologies. Given the foregoing, this study assembles the most recent technical knowledge for the successful application of smart livestock water technology for climate-smart sustainable small-scale agriculture. According to [7], using traditional management techniques along with agro-ecologically based management techniques (biodiversification, water harvesting, etc.) may be the only practical and reliable way to boost agricultural production's productivity, sustainability, and resilience under anticipated climate scenarios.

Small-scale animal husbandry in Africa is becoming more complex in order to overcome the predicted stress that a lack of water will have on animal productivity. Although necessary to guaranteeing food security, this has reduced animal productivity. In this case, small-scale animal husbandry would require the employment of climate-smart livestock water intermediate technologies in order to effectively apply livestock water to problems caused by global warming and climate change. An effort has been made in this chapter to illustrate the connections between food security, small-scale agriculture, livestock water resources, and climate change.

Small-scale animal agriculture's contribution to climate change is recognized for how it affects rural livelihoods and food production while protecting essential water resources for long-term use through adaptable strategies for efficient livestock water management, notably in Africa. A climate-smart livestock water strategy recognizes that there are mitigation solutions accessible throughout the supply chain and small-scale animal husbandry systems. They are largely involved in the management of water reservoirs, water harvesting, and feed production. It highlights how crop-livestock integration and climate-smart agriculture techniques like grassland restoration and management (such as sylvo-pastoral systems) might be beneficial.

The challenges associated with crop mitigation and adaptation to climate change are numerous due to the state of development and resource scarcity, particularly in Sub-Saharan Africa, while coping mechanisms on livestock water to increase animal productivity and improve food security are very scarce. Despite climate change signs showing that livestock water supplies are running low, this issue has received little attention, especially from small-scale animal producers. Africa has few coping mechanisms as a result of institutional poverty in governmental institutions, which makes it difficult for smallholder livestock farmers to manage livestock water.

The effects of climate change on the continent, according to [115], have been escalating and getting worse over time, which has a negative effect on livestock output, especially small-scale animal husbandry that is dependent on rain-fed conditions. Since these mitigation strategies for water scarcity are less expensive for farmers to implement, farmers are particularly interested in them. More coordinated research, awareness, and action are required at all stages of the value chain if agricultural water technology and practices are to be climate-smart.

In order to improve water use efficiency in agriculture and other crucial functions in livestock production, an integrated approach to managing agricultural water resources must be adopted. This can be done by incorporating innovations like water harvesting, micro-irrigation, and livestock production integration. Assisting policymakers in tackling adaptation issues and creating policies to lessen the vulnerability of the farming sector to climate change, the discussion aims to facilitate a better understanding of the potential implications of climate change and adaptation options for agricultural water management. The problems of livestock water use could be efficiently resolved by combining region-specific approaches for both supply and demand side management with the application of modern livestock technologies and smart livestock water management solutions.

11. Integrating Africa indigenous knowledge practices with modern water science to deal with climate change, livestock water and food security

African indigenous knowledge systems in conjunction with contemporary water science can be used to address climate change, livestock water issues, and food security. Techno-science uses contemporary technologies, whereas ethno-science uses methodologies based on local people's understanding of their physical surroundings. Indigenous methods that address small-scale animal farming, climate change, and local knowledge combine to reduce livestock water scarcity and increase food security. They are crucial to constructing small-scale farming systems' resistance to climate change.

Climate change mitigation benefits from careful observation over many generations. Indigenous techniques of managing livestock and their water supplies help to increase biodiversity, lower the danger of low animal output, and lessen the degradation of natural resources. The majority of adaption solutions are sustainable since they are less expensive and based on indigenous knowledge systems, which smallholder farmers appear to prefer. This is typically the second response to climate change because it focuses on identifying alternatives, such as programs and regulations that lessen the vulnerability of people and the environment to the damaging effects of climate change. The two major areas of adaptation are typically ethno-science and techno-science [116].

Indigenous knowledge can be used with socio-institutional and technological developments produced by local resource users to increase livestock water use. It serves as an illustration of how scientists and technical consultants in research and development organizations can combine regional inventions in livestock water, engage the public in discussion about the concepts behind them, and explain in scientific terms how they function and how they relate to other inventions. It supports a research approach that encourages farmers' creativity by exploiting their local knowledge and improving their ability to adapt to shifting environmental conditions as a result of climate change, which has put strain on water resources. It places a high focus on the role that researchers play in exposing how farmers are coming up with solutions that defy official policy and then working with farmers to reform official policy to encourage and accommodate local innovation. As a result, it recommends one "local solution based on local knowledge" that could increase livestock water productivity: encouraging a strategy of fostering local creativity and taking part in collaborative research with locals who are developing their own solutions based on what they know to maximize scarce water resources.

12. Planning for future adaptation to livestock water stress brought on by climate change in small-scale animal agriculture for food security

Among all the nutrients, water is one that animals need the most. Given its significance, an animal's body weight is primarily made up of water. However, due to irreversible climate change, which has decreased rainfall in the majority of the world, its availability is under threat. An animal's ability to adapt to water stress is influenced by a number of interrelated elements (such as animal management and resources). To utilize the resources available, both the animal and its guardians must adapt to their environment (e.g., land, feed, water, and capital). All elements that either promote or prevent animal adaptation must be considered in any study of an animal's adaptability [117].

In dry and semi-arid areas, local animal genetic resources are more resilient to harsh environmental conditions than their non-native counterparts. Therefore, appropriate breed selection is a highly advantageous method for sustaining animal production in a situation that is becoming increasingly challenging due to climate-related water constraint 108;68]. Livestock water-related adaptations in African agroecological zones have not been specifically researched from a continental standpoint. Water-related adaptations in livestock can be shown to vary by region.

The geographical context affects adaptations, which are very site-specific. An adaptation strategy that is effective in one agro ecological or geographical area might not be appropriate in another. However, social settings, which include cultural and economic elements, vary significantly between the areas [118]. As a result, it is challenging to scale up or generalize livestock water-related adaptation measures across a large area, such as the entire African continent with its variety of smallholder livestock farming systems. At the same time, it means that strategies to adapt livestock to water may be successful in one location but may not necessarily be successful in other locations or in situations that are different. African livestock agriculture activities now heavily rely on the resources provided by dams and rivers.

Climate-smart agriculture, ecosystem-based adaptation, and livestock income diversification are examples of adaptation initiatives. It is important to take specific adaptation measures to minimize and lower the hazards that shifting rainfall patterns pose to animal producing systems and to increase resilience. Through a reorganization of social conditions, the adaptations put into place have improved communities' resilience and decreased their vulnerability. Small ruminant production has become more prevalent, especially in areas with little rainfall, as a result of the growing danger to regular water supplies and, consequently, to food security and livelihood. Farmers are utilizing their adaptation processes and water-use efficiency to do this. Small ruminants, notably desert goats, have developed the ability to adapt to life in water-scarce environments while traveling great distances in quest of food. They will restore any lost weight at the subsequent watering hole. Since breed influences resistance to water constraint, more research is required on adaptable indigenous small ruminant breeds so that breeding and selection strategies can be improved.

The greatest barrier to small-scale animal agriculture's use of livestock water-related adaptation methods is Africa. Mismanagement and a lack of climate finance, technology, knowledge, and data, as well as trust and cooperation within and between communities and governments, as well as uncertainties related to climate model projections, climate variability, and the risk of environmental hazards, are a few examples. Identifying climate-related risks and strains in food and water systems using the best available science, policy, and research to assist governments in implementing data-driven climate adaption plans. Putting money into studies to create and enhance crop insurance, microfinance, and other tools that enable communities to control weather and climate risks and maintain resilience.

13. Future application of genomics to animal breeding for adaptability, productivity and food security

The long-term viability of the livestock sector will probably be significantly impacted by farm animals' ability to adapt to climate change. Utilizing genomic data's useful information is necessary for the effective management of regional animal genetic resources [119]. Despite the associated costs, genomic data is crucial for Africa, particularly for breeding livestock for adaptability, and for effective management to fully realize the potential contribution of local animal genetic resources for food security in the constantly shifting environment brought on by climate change. Since climate change is anticipated to modify the nature and distribution of farming systems globally, methods will be needed to adapt and optimize the world's animal-related food production systems, according to [120]. If genomic technologies are to be useful in this context, large-scale genotyping of animal populations, rigorous phenotypic characterization, and routine sample collection are required.

Understanding the contribution of specific genetic loci to trait variation across geographic space is essential to understanding evolutionary adaptations. New breeds of animals that are better able to adapt to environmental stressors like water stress may emerge as a result of inventive scientific and technological developments in genomic biotechnologies, which include several high throughput methods for genetic improvement in livestock and animal production. The incorporation of molecular data in genetic improvement projects for cattle is now made easier thanks to developments in molecular genetics and high throughput technology for genotyping and sequencing. Additionally, by transitioning from employing markers in linkage disequilibrium across the population to markers used within families, these techniques enable the detection and selection of quantitative trait loci. In order to strengthen genetic resilience to environmental shocks and improve adaptive ability over time, effective breeding programs can be developed and put into practice based on genome research.

The discovery of genomic loci of adaptive value will be made possible by landscape genomic analysis employing whole-genome genotyping [121]. If phenotypes are available, genomic selection has the potential to accelerate both pure- and crossbreeding programs for adaptation [122]. Thanks to species-wide Hap-Map studies our understanding of the genome and its function in adaptation has increased. However, further research on breeding practices and production settings is still needed. More thorough characterization using high-throughput single nucleotide polymorphism (SNP) studies or genome sequencing would be necessary to comprehend the physiological foundations of adaptation. Through a process known as local adaptation, natural selection fosters adaptive phenotypic divergence along environmental gradients.

The cost of local adaptation to a particular set of environmental factors is thought to be the outcome of genetic trade-offs at certain genetic loci, where fitness in other environments is sacrificed to enable local adaptation to a particular set of environmental factors. Estimating the genetic breeding value for resilience traits, evaluating the correctness of values using a four-fold cross-validation approach, and creating a focused SNP panel are further techniques for finding genomic loci connected to adaptability. Whole-genome genotyping enables the finding of genomic regions of adaptive value by using an association mapping approach to locate QTL that alter tolerance to environmental challenges [123]. Diversified AnGR will provide more opportunities to replace populations impacted by harsh climatic events like droughts and floods or to adjust breeds to a changing environment. Although data from natural populations suggests that increasing genetic diversity is selectively advantageous on an individual level, broad genetic variation within a breed will surely provide opportunities for adaptive selection [124]. Although directional selection for adapted traits will presumably work hand in hand with maintenance of variation, the breeding target and markers of adaptation and resistance are still unknown.

Breeding for traits including tolerance to heat, water shortage, drought, and certain diseases should be taken into account. These traits are expected to boost productivity and resilience in scenarios that are predicted to be common as a result of climate change. Genomic analysis may be a helpful tool in animal breeding for adaptation, with a focus on local animal genetic diversity measures linked to local adaptation and selection as well as the genetic architecture of animal resilience to weather fluctuations that have resulted in water scarcity as a novel adaptive trait linked to climate change. Genomic techniques will greatly improve the characterization of available germplasm and investigation of the diversity of genetic resources that are locally adapted, and quicker and less expensive DNA sequencing will increase our understanding of the underlying genetic basis of characteristics, maximizing the use of regional animal genetic resources on the continent. Even if methane emissions from smallholder livestock production systems are anticipated to be modest, using genomic technologies to improve animal resilience is more likely to reduce them. Increasing productivity may also be the most practical course for the future of livestock production.

14. Conclusions

Small scale animal agriculture is deeply ingrained in African societies and involves much more than just providing food; it also has a favorable impact on rural livelihoods and serves as an effective risk management tool due to its diversity and networked nature. Identifying, seizing, and increasing opportunities in livestock water management with a focus on small-scale animal husbandry may be the best available response to climate change and solution to the continent of Africa's food crisis. The diversified and intricate small-scale animal husbandry sector on the continent serves a range of local populations' livelihood needs. Therefore, in order to achieve long-term, sustained adoption of a modified strategy that fosters resilience in agriculture, especially livestock water, any effort to promote climate-smart water agriculture practices must recognize and respect these realities of socio-cultural and economic farmers' livelihoods.

The agricultural water management sector needs to reorient itself in favor of sustainable water service delivery that takes into account the local circumstances, especially in the smallholder farming sector, which is at the core of food production and thus food security in Africa. This suggests a comprehensive and integrated approach to agriculture's use of water that focuses on developing resource resilience and sustainability while also managing risks brought on by climate change in relation to broader social and economic water-related repercussions in agriculture. The management of livestock water needs to be based on a strategy that encourages and mobilizes small-scale farmers to be in the forefront of the fight against their climate induced water scarcity and the development of water resources, as this will translate to ownership and hence improved animal productivity and, ultimately, food security.

Climate-related water scarcity, lack of access, and inadequate and wasteful use of livestock water by smallholder animal farmers in Africa pose a danger to small-scale agricultural production, which has an influence on food security. Due to climate change in arid and semi-arid environments, variable rainfall and water scarcity are recurrent occurrences that have an impact on food security and animal production in Africa. The interaction of climate change and livestock water resources is a relatively unexplored field of research, despite the significance of small-scale animal husbandry to the rural poor in Africa and the enormity of the changes that are projected to affect smallholder livestock systems. This distinguishing feature of small-scale animal agriculture is that farmers usually have limited resources to respond to challenges like failed rains and prolonged dry spells that aggravate water scarcity and subsequently decrease animal performance.

Little is known about how the climate, rising climate variability, and their effects on water scarcity and food security interact with other change agents in small-scale animal agricultural systems and in more general trends in agriculture development on the continent. Small-scale livestock systems are among the most vulnerable to water stress brought on by climate change, and they are changing swiftly, with significant regional variation in how households react to change, which may have implications for food security. It is suggested to do broad research on the potential responses of smallholders and pastoralists to water stress brought on by climate change. If the demands of vulnerable small-scale animal farmers in the future decades are to be adequately met, research and development objectives on the impact of climate change on livestock water, animal productivity, and food security may need to be reviewed to align the focus depending on the socio-cultural, economic and environmental community aspects.

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