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Impact of water stress on adaptation and performance of sheep and goat in dryland regions under climate change scenarios: a systematic review

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Abstract Climate change is shifting rainfall patterns, air temperature, river flows, and sea levels globally, resulting in changes in ground and surface water quality due to salinization, especially in arid and semiarid regions. During dry periods, the main water quality issue is a high quantity of salt in the water. Whilst water with fewer than 3,000 mg/L total salts is beneficial to all livestock species, tolerances vary greatly based on conditions and circumstances. Understanding the normal salt tolerance of animals without harming their production and health is important for sustainable livestock production, especially in dry areas. Understanding the normal salt tolerance of animals without harming their production and health is important for sustainable livestock production, especially in dry areas. Thus, this review examined the physiological, behavioral, hematological, and biochemical responses of sheep and goats in dryland areas under climate change scenarios. Despite changes in physiological, blood, biochemical, feed and water intake, sheep and goats adapt to salinity levels to drinking water in arid environments. Adaptable and native breeds are known to be more tolerant of saline water than selected exotic breeds. Small ruminants experience a decrease in food intake and weight, a decrease in breathing rate, and an increase in blood metabolite concentration when the salt in their drinking water increases. The concept that native and adapted small ruminant breeds can withstand high water salinity is gaining popularity in scientific research worldwide. More research is needed to investigate the water tolerance capabilities of adapted breeds, especially in dry and water-saline regions affected by climate change.

Keywords: climate, response, ruminants, water

1. Introduction

Global warming and unsustainable management have influenced agricultural production in the dry land, leading to food insecurity and loss of biodiversity (Ahmed et al 2022; Hirwa et al 2022). The negative impact of climate change, particularly in the semi-arid regions of the world, is due to the rapid melting of glaciers and prolonged droughts, leading to significant declines in agricultural development (Ullah et al 2021). In global warming, water and soil salinisation are major global problems and have a major impact on animal and plant health and production. Salts are more evident in semi-arid coastal agricultural areas, especially in arid regions of the world (Hashem et al 2018; Dye et al 2020). The rise in sea level is associated with an increase in global warming caused by the melting ice sheet melting and thermal expansion of seawater (Turner et al 2022). As the sea level rises, salinity increases in surface and groundwater through the penetration of saltwater. The long-term effects of rising temperatures and decreasing precipitation for 30 years demonstrate a positive link with increased soil salinity in dry landscapes due to less salt over leaching in soil and water (Bannari and Al-Ali 2020). On a global scale, high salinity affects 50% of the entire farmed and irrigated farmland (Cheng et al 2020; Olson et al 2022). Irrigation with saline water, low precipitation, and excessive evapotranspiration are essential elements that drive agricultural fields to salinate at a rate of 10% each year (Sakho-Jimbira and Hathie 2020). By 2050, more than half of the arable land would be salinised at the current rate (Senker 2011). As a result, as freshwater becomes contaminated, lake water becomes an important source of water for drinking and other purposes (Earman and Dettinger 2011), and it is also affected by climate change in its physical and chemical response, which will become more pronounced in the future. It is also affected by climate change in its physical-chemical response, which will become more pronounced in the future (Jeppesen et al 2014). Sheep and goats are ideal animals for poor and marginal farmers to keep because of their incredible disease resistance, dexterous grazing behaviour, high feed conversion efficiency, and drought tolerance, particularly in Sub-Saharan Africa (Ciliberti et al 2022)(Leite et al 2018). Animals in dry areas, on the contrary, are subject to water stress for most of the year (Sejian et al 2015). Therefore, evidence-based stress-tolerant animal species should be selected to deal with stress and shock conditions.

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Goats and sheep are the most efficient animals in water use under semiarid conditions due to their smaller size and better use of ingested and excreted water, which is associated with adaptive processes that increase the efficiency of water use and reabsorption along the digestive tract, which maximises its use and metabolism during scarcity (Araújo et al 2010). The maximum safe level of salt that animals can tolerate is based on environmental conditions, breeds, species, and diet (Mdletshe et al 2017a; Umar et al 2018). (Assad and El-Sherif 2002) recommended that camels protect themselves from salt stress by lowering the amount of saline water intake, while goats and sheep excreted more urine and increased the filtration rate to reduce the high salt load resulting from their high consumption of saline water. Understanding the physiological and biochemical adaptability mechanisms underlying small ruminant adaptation to a saline load is necessary to develop long-term strategies for raising small ruminants in areas with scarce water or high salt concentrations (Digby et al 2011a). Therefore, the aim of this review was to review the literature on how water quality affects the adaptation and performance of sheep and goats in dry regions under climate change scenarios.

2. Methodology

2.1. Literature sources and search

This review was conducted to identify knowledge gaps in the global literature related to the impact of water quality on the adaptation and performance of sheep and goats in dryland regions under climate change scenarios (Sargeant and O'Connor 2020; Wiryananta, K., Safitri, R., & Prasetyo 2020). The final review paper is based on analysing and using selected journal articles, books, short pieces, and many reports from studies conducted by various scholars, institutions, and organisations. The search for literature for this review focused on articles published from 2000 to 2022 year. The search term like animal descriptions (sheep, goats, small ruminants), water quality (water, salinity, drinking), adaptability (response, toleration of climate change, resilience), and environment (dry, arid, semi-arid) were used. Various electronic databases, such as Scopus, PubMed, Web of Science, AGRIS (agris.org), ResearchGate, Science Direct, Taylor & Francis, Springer, Wiley, various African and Ethiopian journals using Google Scholar, and online libraries of the Ethiopian Institute of Agricultural Research (EIAR) and other National Research institutions. Individual articles from the collected literature were categorized depending on the critical review and the review's purpose. Finally, 100 papers were referred to produce the final assessment of the impact of water quality on the adaptation and performance of sheep and goats in dry places under climate change.

2.2. Eligibility criteria and study selection

The articles were searched and sampled from different search engines published in English, focusing on the impact of water quality on the adaptation and performance of small ruminants, and were considered for systematic review. The criteria for inclusion in the systematic review studies were: Published between 2000 and 2022; complete text articles; English; any tropical country in the world; the sheep or goats or both; case studies and reviews. Articles are excluded because of the lack of full-text access or insufficient abstract data, and there are not clear methods for assessing the impact of water quality on sheep and goats, as well as for experimental experiments and materials other than English.

3. Review of Related Literature

3.1. Concept and Challenges of Dryland agriculture

Drylands are defined as all terrestrial regions where the production of crops, forage, wood, and other ecosystem services is limited by water. They include all lands where the climate is classed as dry, dry-sub-humid, semiarid, or arid, excluding hyper-arid regions (UNCCD 2009). Drylands cover approximately 43% of the continent's geographical surface, represent about 75% of agricultural land, and house nearly 50% of the population, including a disproportionate share of the poor. Livestock raising is one of the most important livelihood activities in Africa's drylands, including sub–Saharan Africa (de Haan 2016; Mekonnen 2016). The vulnerability of drylands is significant and growing due to complex interactions among many distinct causes, threatening the long-term livelihood prospects of hundreds of millions of people. Drylands are particularly vulnerable to climate change due to shifting rainfall patterns and land degradation, which lowers the ability of animals and people to adapt to dryland conditions. Climate change is expected to worsen dry land poverty, food insecurity, and water shortages (Nicholson 2017; Williams *et al* 2018). Water shortages and quality pose a major threat to the small-scale production of small-scale ruminants on subsistence-oriented community farms in dry areas (Halimani *et al* 2021). sustainably developing the drylands and providing resilience to their residents would require addressing a complex web of economic, social, political, and environmental challenges effective adaptive responses can create new and better opportunities for many people, minimize losses for others, and facilitate the transition for all (Peng *et al* 2021).

3.2. Climate Change impacts on Water Quantity and Quality

Global warming has many consequences for environmental systems and human life, including water, ecosystem and health quality (IPCC 2014; Watts *et al* 2015). Hydrological changes caused by climate change will complicate sustainable water management, which is already under enormous pressure in many parts of the world (UNESCO and UN-Water 2020). Furthermore, climate change impacts freshwater ecosystems through changing streamflow and water quality. Changes in rainfall or melting snow and ice impact hydrologic systems by changing the quantity and quality of water supplies (IHP 2015; Ahmed *et al* 2020; Konapala *et al* 2020). Water quality will deteriorate as temperature increases, dissolved oxygen levels fall, and freshwater systems lose their ability to self-purify. Risk factors include increased heat, sediment, nitrogen, and pollutant loads due to heavy rainfall, decreased pollutant dilution during droughts, and disruption of treatment systems during flooding (Whitehead *et al* 2009; Ma *et al* 2022).

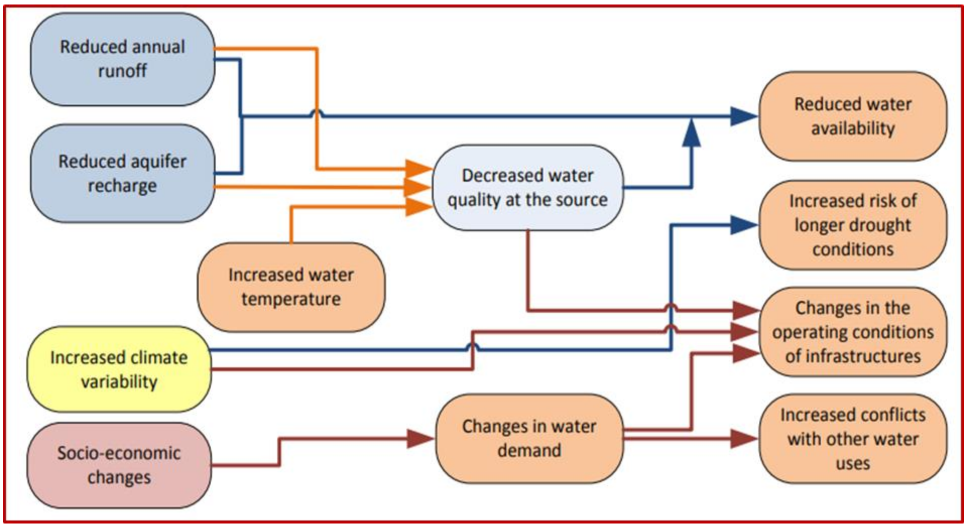

Figure 1 Impacts of climate change on water supply systems. Adapted from (Change 2020).

Climate change will impact the availability, quality, and amount of water for vital needs, putting billions of people and animal species at risk. Water salinisation is a key problem in water quality due to many factors in different regions of the world due to excessive pumping of groundwater and surface water and land use and change (Chang *et al* 2011). Climate variables such as precipitation, surface runoff, and temperature can significantly affect saltwater incursion. Saltwater intrusion occurs when groundwater levels are reduced due to the overexploitation of coastal aquifers (Ranjan *et al* 2006). While local conditions such as river discharge, tidal range and geological setting are essential, climate change and rising sea levels are expected to worsen the intrusion process. Excess irrigation for food production, particularly in dry and semiarid areas, discharge from industrial and mining activities, salt used for deicing in cold climates, effluent from sewage treatment plants, and reduced upstream flow owing to damming are further factors in water salinisation (Cañedo-argüelles *et al* 2013).

Climate change-induced changes in water quantity and quality are expected to have an impact on food availability, stability, access, and use. Moreover, sea-level rise is expected to expand areas of salinisation of groundwater and estuaries, reducing fresh water supply for humans and ecosystems in coastal areas (Bates et al, 2008). This is expected to reduce food security and increase the vulnerability of impoverished rural farmers, particularly in the dry and semiarid tropics, as well as in Asia and Africa (UNECA 2011).

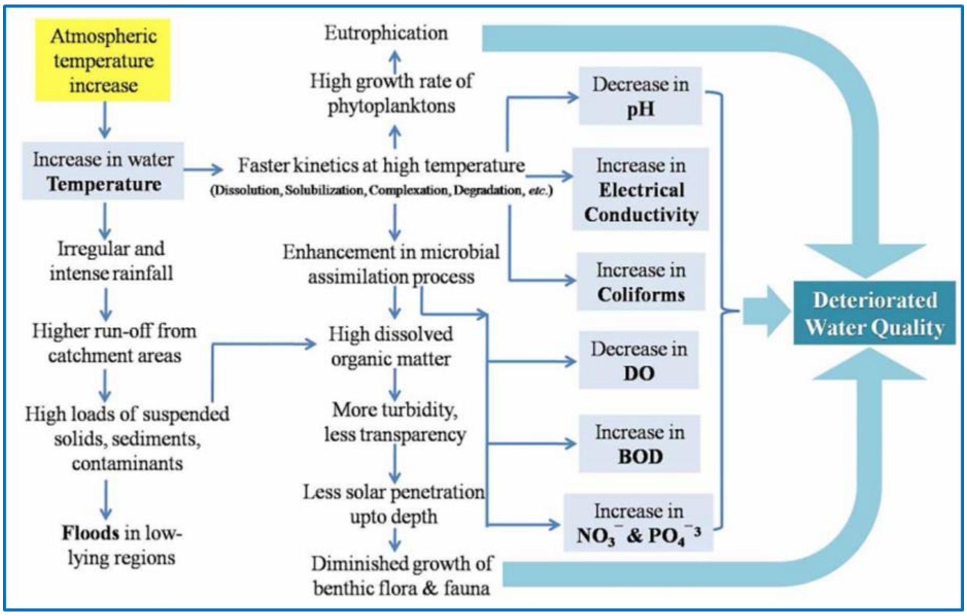

Figure 2 Impact of climatic change on water quality Adapted from (Change 2020).

3.3. Water quality for livestock species

Water is the most important and neglected nutrient for the health and production of animals. Animals need water to control body temperature, digest food, lubricate joints, develop muscles and perform almost any other biological function of the body (Emon 2018). The quality of livestock drinking water is critical for animal production and health. Water is an important but often overlooked nutrient. Livestock water needs are affected by many factors, including size, productivity, diet and environmental conditions(Meehan *et al* 2021). Animals acquire water from a wide range of sources; nevertheless, surface waters are frequently utilised by animals for most of the year. Higher levels of water pollution can affect water and feed intake and animal performance (Mostrom and Ensley 2020). Water quality fluctuates yearly, even from the same source, and meteorological events such as drought or excessive rain have a significant impact. Water quality varies according to geographic location, environmental and industrial activity, climatic conditions (such as snowfall, rain, and drought), and may also be affected by human activities and water management practices (McDowell and Wilcock 2008; Dufour 2013; Mujere and Moyce 2016). Water quality is influenced by several aspects, such as odour and taste, chemical characteristics (pH, dissolved solids, total dissolved oxygen, and hardness), toxic substances (heavy metals, toxic minerals, organophosphates, and hydrocarbons), excessive mineral concentrations (nitrates, salt, sulfate, and iron) and the presence of living organisms (bacteria) (Meehan et al, 2021). Excess mineral levels, a high bacterial load, persistent organic pollutants, and an elevated level of heavy metals are the main causal factors of water quality at high altitudes. Drinking poor availability and water quality will affect animal health and productivity in high and low-altitude areas (Giri *et al* 2020). Total dissolved solids (TDS) are a gravimetric assessment of all inorganic (minerals, metals, salts) and organic (pollutants, pesticides, hydrocarbons) substances that pass through a filter. It makes no distinction between the types of chemicals found in water. TDS and salinity are often used interchangeably, assuming all dissolved solids are salty (Meehan et al, 2021; Mostrom and Ensley, 2020). Salinity is defined as the mass of dissolved elements in a solution, and it is frequently quantified indirectly by measuring total dissolved solids (TDS), total soluble salts (TSS), or electrical conductivity (EC). The most common salinity cause is sodium chloride, but bicarbonate, sulfate, calcium, magnesium, and silica levels can all be important (Higgins and Gumbert 2008).

Table 1 Recommendations for livestock water used based on total dissolved solids (TDS).

TDS (ppm or mg/L)	Effects of Livestock
< 3,000	Usually satisfactory for most livestock
3,000 – 5,000	May not cause adverse effects for adult livestock. Loose stool or poor feed conversion could affect growing/young livestock.
5,000 – 7,000	Should not be consumed by pregnant or lactating females. Usually, a laxative may result in reduced water intake
7,000 – 10,000	Do not use it for swine. Do not use it for pregnant or lactating ruminants or horses.
>10,000	May cause brain damage or death

Adapted from (Meehan et al 2021)

Water can act as a reservoir for various disease organisms and poisons. Bacteria are a prevalent water pollutant that can negatively affect livestock health. Infertility, foot rot and low milk production can all be caused by high concentrations of bacteria in drinking water in livestock drinking water (Emon, 2018). Manure in stagnant water is a common source of pathogens and can contribute to blue-green algae problems, harming animals. Blue-green algae grow in warm weather with light winds. Blue-green algae can poison cattle, causing muscle spasms, liver damage, and death if stagnant water is contaminated with manure or other nutrients. Water resources should be checked for algae and other hazardous organisms, especially during hot and dry seasons (Pfost *et al* 2001). However, tolerance to minerals (total salts) in water supplies varies by animal type, with poultry being the most sensitive, hogs being moderately susceptible, and ruminant animals being the least sensitive. A total soluble salt content of less than 1,000 mg/L is considered acceptable for all types of livestock with low salinity levels (Parker and Brown 2003)

3.4. Small Ruminants, Climate Change and Water

Climate change poses a major global threat to the long-term sustainability of livestock systems because it affects feed and water supply, feed quality and disease, and production is most effective in the best environmental factors (Cheng *et al* 2022; Ma *et al* 2022). The availability and sustainability of safe, high-quality drinking water is a worldwide concern. Such uncertainties endanger animal output, which has a knock-on effect on food security. Small ruminants, such as sheep and goats, seem promising to overcome this problem because of their ability to thrive in water-restricted areas and adverse environments. They have different morphological, behavioural, biochemical, cell, and molecular properties in the blood that allow them to live in other tropical conditions (Akinrinmade and Akinrinde 2012; Alam *et al* 2013; Mandal *et al* 2018; Akinmoladun *et al* 2019; Formiga *et al* 2020). Small ruminants, including sheep and goats, are recognised as ideal models of animals for climate change because of their remarkable endurance of thermal and drought, ability to thrive in limited pastures and resistance to disease (Nasri *et al* 2011).

Water is considered one of the most important nutrients in quality and quantity, consuming more than other nutrients in livestock species. It covers almost 98% of the molecules in the animal organism (NRC 2007; Gerard 2016). However, water quality is a bottleneck in arid and semiarid regions, especially during the dry seasons. Water quality refers to factors such as colour, odour, taste, bacterial content, mineral content, salinity, and the amount of inorganic or organic chemicals used to decide water's acceptability for a specific purpose (Curran 2014; Yıldırır 2020). Water salinity and contaminants such as blue-green algae, organic compounds, heavy metals, and chemicals are major concerns for livestock water quality. The salinity of the water is defined as the sum of all salt ions dissolved in water, including sodium, calcium, magnesium, chloride, sulfate, and carbonate (Ensley, 2013; Mostrom and Ensley, 2020). Furthermore, excessive saline water consumption might decrease intake, resulting in production loss and salt illness in animals. Reduced water usage owing to pollution causes mineral imbalance. Some salts and other elements, when present in high concentrations, can hinder development and reproduction, as well as cause illness and death (Sallenave 2016). Excess magnesium, calcium, sodium, and chloride raise salinity and can be dangerous. The sulfate ion is the most common component of salinity, and more than 1,500mg sulphate/l reduces copper status in cattle. High alkaline water can cause gastrointestinal ups diarrhoea head and decreased feed intake and feed conversion (Naqvi *et al* 2013, 2015). Although animals may survive in high-salinity water for a few days, salinity tolerance varies according to age, species, season, and physiological factors.

3.5. Impact of drinking water salinity on sheep and goat performance

Good quality water is critical for livestock health. The excessive water consumption of livestock is a significant environmental drawback. The major challenges with water quality during dry periods are high salt levels. Furthermore, high saline water in dry or semiarid environments can reduce the quality of the products derived from these animals (Costa *et al* 2019). Water intake is an important responsibility for setting up the adaptive capacities of the animal. Water consumption in small ruminants may be influenced by the concentration of salts in drinking water (Minka and Ayo 2010; Sejian *et al* 2012, 2014). Salt (sodium chloride) ingestion in water or feed, such as salt added to the diet or while grazing saltbush, affects sheep feed intake and water intake, as well as the hormonal management of both energy balance and salt and water balance. The varied sensitivity of feed intake to salt ingestion from food or drinking water may be attributable to different responses of sheep's digestive systems to salt diet and salty water (Digby *et al* 2010, 2011b).

Table 2. Effect of water salinity levels on sheep and Goats by different authors

Influenced variables	Responses of animal	Threshold water salinity levels	References
Body weight and feed conversion	No influence on sheep	7952mg/L	(Tulu et al 2022)
DMI and WI	Decreased in Boer goat	15%TDS	(Thiet et al 2022)
BW, DWG, DMI and apparent digestibility of nutrients	No change in Santa Inês lambs	8326 mg/l	(Reneu et al 2020)
Water intake	Increased in Santa Inês lambs and Alpine goat	8326 mg/l	(Reneu et al 2020; Costa et al 2021)
Intake and nutrient digestibility and milk yield and composition	No influence in lactating goat	8326 mg/l	(Paiva et al 2017; Costa et al 2021)
Performance production meat yield, sensory parameters and histological structures	Bad influence on Barki sheep	5980 ppm TDS	(Zayed 2022)
Dry matter intake and water intake	Influenced by Surti kids	6000ppm	(Harini et al 2022)
Dry matter intake and water intake	Highly influenced by goat	1.5%Nacl	(Runa, Brinkmann, Riek, et al 2019a)

3.5.1. Water intake

Animal intake is one of the factors responsible for production efficiency. Animals' tolerance for saline water varies considerably. However, small ruminants have a higher tolerance. Water intake response to a load of elevated salt was higher in sheep than in a goat (Attia-Ismail *et al* 2008). Under tropical conditions, the salt of drinking water significantly affected the dry matter and water intake of Surti kids without affecting body weight gain (Harini *et al* 2022). However, (Yousuf *et al* 2016; Yousfi and Ben Salem 2017) found that offering saline water for barbarine lambs increased water intake and similarly increased water consumption of sheep as salinity level increased was observed (Moura *et al* 2016). The increased volume of urine required for salt excretion stimulates increased water consumption by all animal species. It is also the primary physiological mechanism for reducing high salt consumption by excreting through urine. Younger goats were more sensitive to drinking water salinity because their salt taste receptors were more susceptible to water salinity (Runa, Brinkmann, Gerken, *et al* 2019; Runa, Brinkmann, Riek, *et al* 2019b; Runa *et al* 2022). In contrast, many other studies have revealed that water intake decreased when the salinity level in drinking water high because of the reduced palatability of saline and salt stress. Another finding revealed that the average daily water intake was reduced in non-lactating female Nguni goats that offered 5.5 and 11g NaCl/l in drinking water compared to those offered in reservoir water 0.033g TDS/l (Mdletshe *et al* 2017b). These findings suggest that animals consume more water when exposed to low saline levels; conversely, when exposed to high salinity water, animals reduce water to avoid salt stress from the saline water. Furthermore, the young animal body includes more water, and at lower salt concentrations, a control mechanism is engaged by raising the Na+ concentration in the tissue. Because of the adaptive response to salt load at high salt concentrations, colloidal plasma osmolality may rise, resulting in reduced water loss from the cells (Zoidis and Hadjigeorgiou 2017).

3.5.2. Feed intake and Body weight change

Dry matter intake is essential in feedlot sheep performance since it is a driver of nutrient absorption required for animal maintenance and growth. Notably, DM intake is also influenced by animals' ability to reduce feed particle size through rumination, hence easing its passage through the gastrointestinal tract (Wanapat *et al* 2015). Multiple factors determine animal feed consumption, including water intake and quality. Water salinity is one of the most critical factors affecting animal feed and nutrient intake (Harini et al, 2022; Meehan et al, 2021; Thiet et al, 2022). Feed intake decreased as water salinity increased. This is because water intake is directly tied to feed intake (McGregor, 2004b), influencing growth. Similarly, Yousfi and Salem (2017) found that administering NaCl in water at 11 and 15 g/l reduced feed consumption in barbarine sheep. Mdletshe et al (2017) showed in goats that were raising salinity levels in drinking water from 0 to 5.5 and from 5.5 to 11g TDS / l significantly reduced average daily feed consumption. However, in crossbred Santa Inês sheep, (Moura et al, 2016) discovered that water salinity levels (640, 3188, 5740, and 8326 mg TDS/l) did not affect dry matter intake. Offering brackish water with a TDS of 6900 mg/l did not affect feed intake in Boer and Spanish yearling wether goats (Tsukahara et al, 2016). In contrary, according to Runa et al (2019), increasing salinity tends to improve feed intake in the Boer goat because the tiny quantity of salt in the drinking water stimulates microbial activity in the rumen, which in turn increases digestion. When the rumen bacteria adapts to the elevated salinity, DM intake remains constant (Paiva et al 2017).Because greater salinity stimulates the CSF to decrease parotid salivary production and increase ruminal pH, goats' average daily feed consumption decreases (McGregor 2004, Eltayeb 2006, Mdletshe *et al* 2017, Zoidis and Hadjigeorgiou 2017).

Different studies reported that different salt levels in drinking water affect the body weight of sheep and goats under other management. For instance, some few researchers suggest that the consumption of water salinity had an impact of performance of goat (Eltayeb 2006, Mdletshe et al 2017, Zoidis and Hadjigeorgiou 2017), and sheep (Hekal 2015, Yousfi *et al* (2016). The possible reasons for the reduction in body weight gain were the reduction in feed and water intake of animals and environmental conditions. According to several research, saline water has no effect on body weight gain. Yousfi et al (2016) discovered that giving water with 7g NaCl/l had no effect on the average daily growth in Barbarine lamb.A study by Runa *et al* (2019) confirmed higher body weight gain (52.8 vs 42.7 kg), feed consumption (1.02 vs 0.822 kg/day), and water intake (0.721 vs 0.426 l/day) in older than young goats offered 1.5% NaCl in drinking water. The salt content of water and diet also affects the tolerance of livestock to high saline water. Drinking water with a guideline value of increased feed and water intake in animals but too saline water affects animal performance and health care (Attia-Ismail *et al*, 2008). While livestock grazing green pastures are more tolerant of drinking high saline water than those grazing dry pastures or saltbush, the high moisture content of green feed dilutes the salinity levels of the water supply (Gerard 2016).

3.6. Adaptation of Sheep and Goats to Water salinity

Animal performance is essential for checking animals' physiological responses to their environment (Roger A. Eigenberg et al, 2013). Physiologically, ruminant breeds of arid regions show many adapted mechanisms to conserve water in times of heat and drought. Adapted breeds use a reduction in the volume of urine and faecal moisture. The physiological features of arid animals like goats and desert sheep that handle a superior digestion ability include large salivary glands, the large absorptive area of their rumen epithelium, and the ability to rapidly change the volume of the foregut in response to environmental changes. Mcgregor (2004) reported that Goats safely used saline water with up to 11,000 mg TDS/L and 470 mg/L. Goats can tolerate high-salt water and prefer water with up to 12,500 mg/L for freshwater, but they must be adapted to salt water. Evidence of goats' ability to survive on seawater was found, and, under all circumstances, they were adapted and had access to shade and moist herbage. During drought, goat producers should check the salinity of their water supply, particularly new water sources. However, the long-term effects of increased saline water intake and elevated trace element exposure in adapted goats should be investigated. Zoidis and Hadjigeorgiou (2017) reported that young male-adapted goats could tolerate elevated salinity levels in drinking water, for at least two weeks, without harmful effects. The tolerance to salinity of animals is based on the species, age, and physiological conditions of small ruminants. Many scholars

(Araujo *et al*, 2010; Gerard, 2016) showed that animals under physiological stress due to pregnancy, lactation, or rapid growth are susceptible to salinity effects. Differences in salinity are reflective of the specific metabolic needs of animals.

3.7. Adaptation mechanism of sheep and goat to water salinity

3.7.1. Behavioral mechanisms

Animal behaviour can be used to show the quality of the whole production system, including individual activities of the animal in its social and physical environment (Custodio *et al* 2016). The Ingestive behaviour is a valuable tool for evaluating the animal response to certain diets, because it allows for understanding the factors acting on the regulation of the intake of feed and water, thus making it possible to set up adjustments in the feeding management of animals aiming at the better productive performance (Carvalho et al, 2004). Feeding behaviour is affected by environmental constraints, including water stress. A few studies reported that water stress influences sheep and goats' behaviour. For example, Moura *et al* (2016) reported changes in feed efficiency, rumination, and water consumption with the elevation in salinity levels of water offered to sheep. Elevation and air temperature, for example, may induce behavioural changes in sheep, such as decreased feed intake and increased water consumption (Furtado *et al* 2020).

Furthermore, consuming saline water causes alterations in the efficiency of eating, rumination, and chewing (Moura et al, 2016), affecting animal production performance. Similarly, (Leite *et al* 2019) found that Morada Nova females sheep that consumed water with a salinity level of 9.0 dS/m spent more time drinking water than those consuming water with a salinity level of 3.0 dS/m. The finding indicated that sheep and goat were adapted to water salinity by changing or no changing their behaviors and ingestive behavior.

3.7.2. Thermoregulatory mechanisms

Sheep are homeotherms; they try to support their body temperature within a fixed range, even under harsh climatic conditions. Thermoregulation traits, including rectal temperature, respiration rate, pulse rate, and thyroid activity, are the major indicators of the adaptability of animals to stress. Normal rectal temperatures range between 38.3 and 39.98^{o}C under thermo-neutral conditions. Still, when exposed to heat stress (33-38.58^{o}C), the rectal temperature increases significantly, and when surrounding temperatures exceed 42.8^{o}C, it becomes life-threatening to the sheep (Marai *et al* 2006). Reports on the effect of water stress on the rectal temperature in sheep and goats are inconsistent. According to (Hekal 2015) rectal temperature was increased in Barki ram lambs offered saline water having 2886ppm TDS compared with the control group (275ppm TDS).In contrast, many studies showed that water salinity did not affect rectal temperature. For example, saline water did not affect the rectal temperature in goats (Eltayeb, 2006; Mdletshe *et al*, 2017). Similarly, increasing the TDS content in drinking water had no significant effect on the rectal temperature of Baluchi lambs (Vosooghi-Postindoz *et al* 2018).

Some studies clarified that the respiration rate increases when drinking saline water. For example, Hekal (2015) showed that Barki ram lambs offered saline water having 2886ppm TDS had a higher respiration rate than the 275ppm TDS group (55.34 vs 48.8 breaths/min., respectively). Similarly, Eltayeb (2006) found that the respiration rate was significantly ($P<0.05$) higher during summer at 2:30 pm in female Nubian goats offered saline water (0.8, 1.2, 1.6, and 2.0% NaCl during four consecutive periods of 10 days) than those offered tap water. However, in goats, Mdletshe *et al* (2017) found that the respiration rate was not influenced by saline water holding 0, 5.5, or 11g of TDS / l. The pulse rate of animals is also affected by water salinity. The observed increase in pulse rate of goats at 11g TDS/L compared to the 0.0g TDS/l and 5.5g TDS/l saline (Mdletshe et al, 2017). Similarly, an increase in salinity level from 6.0 to 9.0dS / m resulted in a significant reduction of 12.2% in the pulse rate of Morada Nova female sheep (Leite *et al,* 2019). A higher pulse rate shows that animals were directing more energy to the heart to excrete excess salt from the body system. However, Yirga (2019) reported the absence of the effect of water salinity levels of up to 17 g TDS/l on thermoregulation traits of growing and mature Blackhead Ogaden sheep and Somali goats. Additionally, thermoregulatory variables like rectal temperature, respiration rate and pulse were in the normal range for sheep consuming water salinity of lake water (Tulu et al, 2022). These indicated that small ruminants have an adaptation tolerance to water salinity without harmful effects under different environmental conditions and management systems.

3.7.3. Blood Hematological Responses

Blood is an important and reliable medium for deciding a particular animal's health status (Bhat *et al* 2011). The blood system is affected by temperature fluctuations and serves as a key marker of physiological stress reactions. Water stress both in quantity and quality is the most essential part in altering haematological variables like red blood cell count (RBC); hematocrit value (HCT); haemoglobin concentration (HGB); mean corpuscular volume (MCV); mean corpuscular haemoglobin (MCH); RBC distribution width (RDW); total white blood cell (WBC) in sheep and goats, especially in arid and semiarid regions where water is scarce (Runa et al, 2022; Tulu et al, 2022; Vosooghi-Postindoz et al, 2018). Numerous factors, including species, breed, sex, age, nutrition, illnesses, physiological stage, water quality and temperature change, might influence haematological value trends (Agradi et al, 2022; Akinmoladun et al, 2020; Anya et al, 2018).

Many studies have revealed that drinking saline water decreases blood haemoglobin levels (Hb) in sheep and goats.

For instance, in female Nubian goats, Eltayeb (2006) showed that during the summer season, blood Hb was decreased in goats offered saline water (1.2 and 1.6% NaCl). Similarly, in Barki sheep, a decrease in haemoglobin concentration (Hb) was seen in the saline water group (2800ppm TDS) than that in the tap water group (10.74 vs 2.38 mg/dl, respectively) (Heka, 2015). On the contrary, many studies showed saline water did not affect blood Hb. Yousfi *et al* (2016) showed that saline water (7 g NaCl/l) did not affect blood Hb in barbarine lamb. Zoidis and Hadjigeorgiou (2017) reported that PCV increased significantly increased (P<0.001) in castrated goats offered saline water (20%NaCl) compared to those offered tap water. In contrast, blood PCV was decreased by saline water in some experiments. Eltayeb (2006) showed that blood PCV was decreased (P<0.05) in female Nubian goats offered saline water (1.2 or 1.6% NaCl) compared to those offered tap water. However, saline water did not affect the blood HCT values in, Barki lambs (Hekal, 2015) and Barbarine lambs (Yousfi *et al,* 2016). Additionally, in goats, Tsukahara *et al* (2016) noted that brackish water having 6900 mg of TDS / l did not influence blood HCT values.

Different studies show that drinking saline water in sheep and goats influenced red blood cell count and indices. Zoidis and Hadjigeorgiou (2017) presented that saline water (20% NaCl) increased (P<0.001) red blood cells count (RBCs) and increased the mean corpuscular haemoglobin concentration (MCHC) in castrated goats compared with the freshwater group. In contrast, in Barbarine lamb, Yousfi *et al (*2016) found that the count of RBCs was not affected by saline water having 7g NaCl/l. Similarly, in Baluchi lamb, raising the content (8000 mg / l) in the water did not significantly affect the counts and indices (Vosooghi-Postindoz et al, 2018). Furthermore, the values of mean corpuscular haemoglobin (MCH) increased (P<0.001) at 0.5 and 5% NaCl and then returned to the control range at 10% and 20% NaCl. Although the values of mean corpuscular volume (MCV) decreased (P<0.001) at 0.5, 5, and 10% NaCl, they latterly returned to the control range at 20% NaCl, while the platelet count was not affected. Furthermore, in Barbarine lamb, Yousfi *et al (*2016) found that offering saline water (7g NaCl /l) did not affect blood WBC, MCV, MCH, MCHC, and platelet count. Therefore, the change in haematological variables of sheep and goats might be attributed to the species, age, breeds, water salinity levels and environmental factors. Variations in hemato-biochemical variables were reported in young and old goats and male and female goats (Runa et al, 2019), implying that goats exhibit varying tolerance abilities for increasing drinking water salinity based on their sex and age. Younger animals were shown to be more sensitive to increased salt concentrations and less resistant to it than older animals

3.7.4. Changes in Biochemical variable

Knowledge of biochemical blood variables is necessary to define the biochemical profile, energy metabolism, metabolism disorders, liver function, and bone abnormalities and, based on them, to assess the level of adaptation of animals to climatic adversities (Swenson and Reece, 2006). Many studies said that saline water increased blood glucose concentrations. Hekal (2015) reported that plasma glucose increased in Barki ram lambs offered saline water (2886 ppm TDS) compared to the tap water group. Also, in Barbarine sheep, Yousfi and Salem (2017) reported increased glucose in groups offered saline water with 11 or 15g NaCl/l TDS compared with the freshwater group. However, Tsukahara *et al* (2016) noted that the blood glucose concentration was higher in Boer and Spanish yearling goats that consumed tap water than those offered water having 6,900 mg of TDS/L.

On the other hand, in Barbarine lamb, Yousfi *et al* (2016) found that offering water with 7g NaCl/L in lamb did not affect the serum glucose level. On the other hand, Hekal (2015) saw that saline water having 2886 ppm TDS increased the plasma total protein compared with the 275 ppm TDS group. Similarly, Zoidis and Hadjigeorgiou (2017) showed that complete protein and albumin concentrations in the blood were significantly increased in the water offered to castrated goats having 20% NaCl compared to the 0% NaCl group.

Hekal (2015) found that blood globulin concentrations increased in Barki ram lambs offering 2886 ppm TDS water compared to tap water. On the contrary, Zoidis and Hadjigeorgiou (2017) showed that saline water holding 20% NaCl did not affect blood globulin in castrated goats. The increased blood cholesterol resulted from saline water containing 8000mg/l TDS in Baluchi lambs (Vosooghi-Postindoz et al, 2018). On the other hand, many studies reported that saline water decreased blood cholesterol. Hekal (2015) found that offering saline water (2886ppm TDS) decreased plasma cholesterol in lambs compared to the tap water group. Also, Mehdi *et al* (2016) found that the serum cholesterol and triglyceride concentrations were decreased in Barbarine sheep offered saline water (10% NaCl) compared with the 5% NaCl group. Runa *et al* (2019) showed that saline water (10350 mg of TDS / l) significantly increased plasma triglycerides in growing Boer goats. However, (Mehdi *et al* 2016) found that a high concentration of saline water (10% NaCl) decreased serum triglyceride concentrations during the first month of lactation in Barbarine sheep (P<0.05) compared to those offering low red concentration (5% NaCl).

Minerals such as chlorine, potassium, and sodium are key components of body fluids that provide osmotic equilibrium, acid-base balance, and membrane permeability and assist in regulating water distribution in the body. Many authors observed plasma electrolytes in healthy goats (Paiva et al, 2017; Runa et al, 2019; Zoidis and Hadjigeorgiou, 2017) and sheep (de Matos et al, 2019; Mehdi et al, 2016; Tulu et al, 2022) were within normal ranges. Compared to freshwater, saline water has significantly high Na+ and Cl- concentrations in goats consuming saline water containing the 1.5% group; however, the animal remained in the reference range and maintained constant plasma Na+ and Cl- concentrations. This adaptation mechanism involves growing crossbred goats drinking saline water by managing water and salt balance by lowering Na+ and Cl- reabsorption in the renal tubules and boosting excretion through urine. The ability of animals to tolerate varying salt levels in drinking water may be connected to renal function (Thiet et al 2022)

3.7.5. Change in kidney and liver function

The kidney's key responsibilities are water retention, electrolyte balance, selective reabsorption, and salt chloride conservation (Levey 2006). The kidneys are also in charge of excreting harmful metabolic waste products, specifically the nitrogenous molecules urea and creatinine. Urea is synthesised in the liver using NH_4^+, the product of protein catabolism, and is released into the blood. The kidneys excrete urea to remove excess N intake that was not used for maintenance or production, or it is recycled through saliva or by reabsorption into the rumen to be used by rumen microflora (Huntington and Archibeque 2000). Yousfi and Salem (2017) reported that plasma urea was significantly (P<0.001) higher in sheep that received saline water holding 11 or 15g NaCl/L compared to those offered tap water, suggesting an alteration of kidney function. In Barki sheep, (Ghanem *et al* 2018) showed saline water (4557 or 8934 ppm TDS) for nine months significantly increased serum urea compared with the tap water group. Comparable results were seen in castrated goats (Zoidis & Hadjigeorgiou, 2017) and Baluchi lambs (Vosooghi-Postindoz et al, 2018). On the other hand, Mehdi *et al* (2016) reported that serum urea concentration was reduced during the second month of lactation (P<0.01) in barbarine sheep that offered saline water holding 10% NaCl compared to the 5% NaCl group. Creatinine is produced in muscles and excreted by the kidneys in proportion to muscle mass and the rate of proteolysis. Thus, creatinine can be used as a reliable indicator of renal function (Caldeira *et al* 2007). In Barbarine lambs, Yousfi *et al (*2016) found that offering water with 7g NaCl/l significantly increased serum creatinine compared to the freshwater group. Furthermore, in Barki sheep, Ghanem *et al (*2018) showed that saline water (4557 or 8934 ppm TDS) for nine months significantly increased serum creatinine concentrations compared to the tap water group. Similarly, saline water increased blood creatinine in barbarine lambs (Yousfi and Salem, 2017) and goats (Zoidis and Hadjigeorgiou (2017). However, Hekal (2015) showed that plasma creatinine was lower in saline water in the lambs' group (2886 ppm TDS) than tap water group (0.77 and 0.87mg/dl, respectively).

Aspartate aminotransferase (AST) and alanine aminotransferase (ALT) assays are needed to evaluate the liver's normal function. AST and ALT levels are especially high in those with liver problems and damage (Gowda et al, 2009; Habib & Shaikh, 2018). Blood enzymes such as aspartate aminotransferase (AST) and alanine aminotransferase (ALT) are regarded as indicators of liver health, with considerable variations in their concentration showing liver problems (Badakhshan & Mirmahmoudi, 2016). Assad and El-Sherif (2002) observed an elevation in plasma AST and ALT (P<0.05) in sheep offered saline water having 13,535 ppm TDS compared with those provided freshwater group.

Increased renal retention of Na+ is a physiological response to water restriction in different small ruminant breeds, which allows the maintenance of sodium balance in the body. Eltayeb (2006) showed that an increase in NaCl concentration in drinking water increased (p<0.001) the serum sodium level in Nubian female goats. Increased water salinity (0.5%, 5%, 10% and 20% NaCl) increased the plasma sodium (P<0.05) in castrated goats (Zoidis & Hadjigeorgiou, 2017). In contrast, Meintjes and Engelbrecht (2004) reported that plasma sodium concentrations were significantly (P<0.05) decreased in sheep offered saline water having 4.5 or 9g NaCl/l compared with the freshwater group. Related results were seen in sheep (Hekal 2015).

3.8. Importance of salt intake and toxicity

In order to coordinate various physiological processes, macronutrients are nutrients that animals require in sufficient quantities throughout their lives. Among different mineral elements, salt is essential for animals' internal functions and overall health, production, and reproductive capacity (Lata & Mondal, 2021). Even though salt is playing key role in stimulate and enhance animals' appetites, small amount is needed in water and feed they ingest. Because hay is naturally low in sodium, salt supplements are essential (Berger, 2006). Animals have a significantly stronger hunger for sodium and chloride in salt than for other minerals. Small ruminant salt insufficiency symptoms include decreased weight gain and increased water intake (Johansson, 2008). The total dissolved salt content of the water determines the amount of salt required in a meal plan.

Table 3 Recommended sodium intake for feed in sheep and goats (NRC, 2007)

Sodium (g/day)	Sheep	Goats
Maintenance	(0.0108 x BW)/0.91	(0.015 x BW)/0.80
Growing	(1.1 x average DWG)/0.91	(1.6 x average DWG)/0.80
Pregnancy	(105–133 days) (0.021 x LBW)/0.91	(0.034 x LBW)/0.80
Lactating	(0.4 x MY)/0.91	(0.4 x MY)/0.80

BW = Body weight; DWG = Daily weight gain; LBW = Lamb born weight; MY = Milk yield

Sodium chloride poisoning can be caused by excessive intake (direct salt poisoning) or by a water shortage (indirect salt poisoning), often by a combination of these two factors (Gupta, 2012). The concentration of sodium chloride in food or drinking water that meets the physiological demands of the organism without causing toxicity is less than 0.5%. Salt is more toxic when it is in a dissolved or musky form as it can be easily absorbed by the animal's body, compared to when it is in solid form such as salt lick blocks (Kahn, 2010). Sodium and chloride ions handle the osmotic balance in the body. Increased blood osmolality causes thirstiness and stimulates water uptake, and because it affects the antidiuretic hormone, it causes water retention in the organism. This compensation mechanism decreases osmolality and is effective only if the animal has enough water at its disposal. Clinical poisoning symptoms develop within 1-2 days (Gupta, 2012). Therefore, resource-limited smallholder farmers could easily adopt the technique under a traditional farming system in assessing sheep and goats that are negatively affected by saline drinking water.

4. Final considerations and the way forward

Adequate water is required to increase animal production and health; yet, severe and escalating climate change is having a negative influence on worldwide drinking water quality. Salinity is one of the most critical elements in water quality, particularly in dry regions. Although salt is necessary for regulating body water content, muscle and nerve function, and nutrient absorption, excessive long-term salt consumption can interfere with feed and water intake and even cause severe health problems. Animal tolerance to water scarcity and salinity in drinking water varies by species, adaptation, and environment. Goats are more tolerant of salinity in drinking water than other ruminants. Although young animals are more susceptible to water salinity than adults, this does not harm production performance or blood biochemistry.

Additionally, according to their morphologic behavioural, physiological, and biochemical characteristics, small ruminant breeds in arid and semiarid regions show good adaptation to water scarcity and salinity. Further research is needed on an adaptive trait of tropical indigenous sheep and goat breeds, because tolerance to water stress (scarcity and salinity) varies by breed, age, sex, nutrition, and environmental conditions, and can be improved by an effective selection and breeding program. The adaptation characteristics of sheep and goats could be studied by subjecting the animals to levels of water deprivation, salt, and temperature at different management systems. Furthermore, future research is required to determine the optimal level of drinking water salinity that can be provided without impairing performance in various animal categories and age groups and to investigate the interactions between water stress, feed limitation, and high ambient temperatures. It is also essential to test water and heat stress preventive actions, as well as medications for stress relief while focusing on animal welfare and the practical use of these processes in the field. New stress-relief strategies, such as vitamin C supplementation, should be investigated further as a complement to different stress conditions. Water and heat stress mitigation options involve adjusting the environment, management, and breeding, and all three should be researched further to improve the production and welfare of grazing sheep and goats in a changing climate.

Ethical considerations

Not applicable.

Conflict of Interest

The authors declare that there is no conflict of interest.

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