Water resources for livestock in Ethiopia: Implications for research and development

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Abstract

Ethiopia is home to about 35 million tropical livestock unit (TLU), and on average, one TLU requires about 25 litres of water per day. Based on this calculation, the total daily water requirement for livestock is estimated at 875 million litres. This amounts to about 320 billion litres per year. Ethiopia has about 173 thousand km^2 of water bodies that include lakes, rivers, reservoirs, small water bodies, swamps and flood plains. The total lake area in Ethiopia is estimated at 750 thousand hectares. There are nine major rivers, totalling 6400 km with an annual discharge of 63 billion cubic metres, of which the Blue Nile accounts for 80%. Contrary to this however, water is a very scarce commodity for many of the smallholder farmers and their livestock, and the situation is aggravated by seasonal variations in availability of water.

Research and development work on water as a limiting nutrient to animal production and management practices to increase efficiency is rare in Ethiopia. This paper assesses water resources in Ethiopia, examines water requirements for different species of animals and attempts to identify some research and development issues related to development of the livestock sector in Ethiopia. The climatic and environmental conditions in the country are variable. Temporal and spatial distributions of rainfall with consequent large fluctuations in the quantity and quality of feed and variations in ambient temperatures and water availability result in variations in body composition and have a profound influence on the productivity of animals in their environment. It is therefore necessary to undertake studies on water metabolism and requirements for livestock under the relevant environmental conditions and physiological states. Water quality both with respect to drinking water for animals and animal management practices that affect the water resources are other areas of concern that deserve attention. Research has to focus on environmental pollution specifically in waste management in densely populated areas of livestock such as in the highlands and urban and peri-urban areas. Moreover, research should provide information on improving the environment and management techniques to increase water use efficiency and raise animal productivity.

Introduction

Ethiopia is one of the African countries endowed with huge water resources, which include rivers, lakes, reservoirs, small water bodies, swamps and flood plains. These resources are important for fisheries and aquatic resources development, livestock resources, irrigation, power generation etc. The rains in the highlands of Ethiopia, which supply these waters, have significant influence in the livelihoods of downstream countries such as The Sudan and Egypt. As a result, the highlands of Ethiopia are considered as the water towers of Africa. Contrary to this however, water is a very scarce commodity for many of the smallholder farmers.

Livestock are major components of the livelihoods of both pastoralists in the arid and semi-arid lowlands of the country, and the crop–livestock farmers in the highlands. Access to water during the major part of the year is variable and both human and livestock suffer from its shortage. In many parts of the country, animals are trekked to distant watering points once in two or three days. Watering animals is a major occupation for pastoralists and shortage of water often leads to social conflict. In most instances, the quality of available water is poor and is a major source of parasitic infestation to animals. Where both human and animals consume water from the same source—as it happens in most cases—this poses a major risk for public health. Water requirement for animals in urban and peri-urban centres has never been considered in urban planning; and as a result, animals are often forced to consume wastewater with high health risks. This will have significant implications on product quality and public health.

Water resource is pertinent and vital for the existence and development of the livestock sector. It should be recognised that the multiple use of land and water resources lead to various conflicts that arise from the shared use of these limited resources. It is noted that, of a whole variety of purposes of water resources development, which include *inter alia*, rain water harvest, irrigation, hydropower generation and water storage often relegate the fisheries and its ecosystem. It should be stressed that planners and policy makers should be continuously made aware of the importance of livestock in the overall rural development schemes. This paper highlights water requirements for livestock and specifically focuses on opportunities and constraints related to water resources research and development.

Water resources for livestock use

There are three sources of water for the animal: (1) drinking water (2) water contained in feeds and (3) metabolic water. Water contained in feeds consumed (preformed water) is highly variable from feed to feed according to the moisture content, which can range from as low as 5% in dry feeds to as high as 90% or more in succulent feeds (Sirohi et al. 1997). Water derived from dry feeds may be insignificant compared with the total water intake, while that obtained from succulent feeds can supply all the water needs. Sheep would drink little or no water when the water content of the feed is over 70% (Degen 1977; Sirohi et al. 1997). When water content of the feed ingested is low, drinking water is the major source of water intake, and its provision for livestock becomes the main concern. Most of the water that is utilised by the animal's body is ingested either as drinking water or as a component of the feed (Woodford et al. 1984).

The oxidation of organic nutrients during metabolic processes in the body leads to the formation of water (metabolic water) from the hydrogen present. On the average fats, carbohydrates and proteins respectively yield 1.07, 0.56 and 0.40 ml water per gram oxidised, or an equivalent of 0.12, 0.14 and 0.10 ml water per kcal metabolisable energy derived from oxidation (Maynard et al. 1981). For most domestic animals, metabolic water comprises only 5 to 10% of the water intake. Metabolic water may account for up to 15% of the total water intake in sheep (Aganga et al. 1989; Abdelatif and Ahmed 1992; Sirohi et al. 1997) and remains constant provided metabolic rate is constant (Maynard et al. 1981). In certain cases, and in animals consuming less food than required, the production of metabolic water becomes more important, since depot fat and tissue protein are catabolised to supply energy.

Water losses from the animal

Faecal water constituted the least avenue of water loss (18%), but in normally hydrated sheep feacal water accounts for up to one-fourth of the total water loss (Degen and Young 1981; More et al. 1983; Aganga et al. 1989; Abdelatif and Ahmed 1992; Sirohi et al. 1997). Urine water loss is the second avenue of water loss and studies show that it accounts for up to one-third of the total water loss in sheep (Degen and Young 1981; More et al. 1983; Aganga et al. 1989; Abdelatif and Ahmed 1992; Sirohi et al. 1997). It was also observed that there is an increase in urinary water loss with supplementation, which could be related to the higher dry matter intake (DMI) and nitrogen and ash intakes. The increased demand in water turnover/requirement with supplementation was a reflection of the rise in water loss through evaporation and urine, as observed from the decrease in the relative contribution of faecal water loss, but an increase in relative contribution of urine and evaporative water losses with supplementation.

Evaporative water loss represents the remainder of the water loss not collected in faeces and urine, and includes water presumably lost through respiration, perspiration and evaporation from the respiratory tract and the skin. Insensible perspiration and non-panting respiratory water losses are obligatory, whereas losses by panting and sweating come into picture in response to relatively higher thermal stimuli for thermoregulation. Evaporation becomes the major avenue of water loss from the body, particularly under tropical conditions, where evaporative cooling may account for up to three-fourth of the total water loss in sheep (More et al. 1983; Aganga et al. 1989; Abdelatif and Ahmed 1992; Sirohi et al. 1997). Study has shown that even at relatively moderate environmental conditions, evaporative water loss still constituted the major avenue of water loss (55%), and increases with supplementation. The increase in metabolic water loss with supplementation could be due to high metabolic rate caused by high feed and/or water intakes/turnover accompanying supplementation. It has been indicated that water requirement, respiratory rate and evaporative water output are directly proportional to feed intake because of increment in metabolic activities (Aganga et al. 1989). It, therefore, seems that the amount of water used at low levels of feed intake during supplementation is less than at high levels of intake when metabolic rates and cooling requirements become greater. Generally, evaporative water loss followed by urine water loss is considered as important sources of body water loss during supplementary feeding of ruminants.

Functions of water

Accounting for about 99% of all molecules and 73% of the fat free empty body mass (King 1983), water is by far the largest single chemical component of the animal body. From a functional point of view, no other chemical compound has so many distinct and vital roles as water; by far the greatest number of life processes in the body takes place with water as a key substance. Accordingly, water stands second only to oxygen of all environmental constituents immediately necessary for life. While an animal may survive a loss of practically all of its body fat and over half of its protein, a loss of one-tenth of its body water is fatal (Maynard et al. 1981). Since relatively small changes in body water cause profound changes in function, the body water content must remain reasonably constant.

Many of the biological functions of water are dependent upon the property of water acting as solvent for numerous compounds. Water takes part in digestion (hydrolysis of proteins, fat and carbohydrates), in absorption of digested nutrients, in transport of metabolites in the body and in excretion of waste products. Many catabolic and anabolic processes taking place inside the tissues involve the addition or release of water. Water also plays an important role in the animal's thermoregulatory mechanisms. The body temperature is dependent partly on the high conductive property of water to distribute heat evenly within the body and temperature is prevented by high specific heat of water.

Water requirements of livestock

Water requirement by livestock appears to be a very individual and specific characteristic. Such differences are reflected in their respective abilities to withstand dehydration and in their demand for free water. As the demand of the individual animal for water is variable, only average estimates of water requirements in a specific climatic environment are generally indicated (Tables 1 and 2).

Table 1. *Some general guides to water intake of different class of animals.*

Class of livestock	Daily water requirement (gallons/day)
Beef cows	7–12
Dairy cows	10–16
Horses	8–12
Swine	3–5
Sheep and goats	1–4
Chickens	8–10/100 birds
Turkeys	10–15/100 birds

Note: Extremely hot heat-stress weather could increase the high values another 20 to 30%.

Table 2. *Estimated water requirement and voluntary intake of livestock under Sahelian conditions.*[1]

				Wet season air temperature (27°C)		Dry cold season air temperature (15–21°C)		Dry hot season air temperature (27°C)	
Species	TLU[2]	Mean live weight	DM intake	Total water requirement	Voluntary water intake	Total water requirement	Voluntary water intake	Total water requirement	Voluntary water intake
				Litres/day					
Camels	1.6	410	9	50	15	37	35	50	50
Cattle	0.7	180	5	27	10	20	19	27	27
Sheep	0.1	25	1	5	2	4	4	5	5
Goats	0.1	25	1	5	2	4	4	5	5
Donkeys	0.4	105	3	16	5	12	11	16	16

1. Volutary water intake has been calculated from the water requirements by assuming a water supply from the plants corresponding to:
70 to 75% of moisture content of the plants during the wet season
20% of moisture content of the plants during the dry and cold season
10% of moisture content of the plants during the dry and hot season.
2. TLU = Tropical livestock unit is equivalent to an animal of 250 kg live weight on maintenance.
Source: Pallas (1986).

Ethiopia has an estimated livestock population of about 35 million TLU. Assuming an average consumption of 25 litres of water/day per TLU, the estimated daily water consumption is about 875 million litres. This adds up to about 320 billion litres per annum. This requirement is expected to increase due to the increase in livestock population and envisaged improvement in productivity (milk, meat, eggs). Improvements in the dairy sector, for example, will require additional water for milk production and sanitary management.

The water requirement of domestic animals varies between species, between breeds or varieties within species and between individuals within breeds. For example, heavy western breed cows have a higher water intake (60 to 90 litres/day) than zebu cows (25 litres/day with 350 kg live weight (King 1983). The water demands of sheep, goats and camels are not as high as those of cattle. Water requirement increases with growth, and with increases in productive processes such as lactation and egg laying. Lactating cows consume more water to cope with the water excreted with milk than cows of similar weight fed on maintenance level.

Water requirements also largely vary according to other factors such as food intake, quality of the food and air and water temperature. Water consumption increases with increasing dry matter intake and increasing temperature. *Bos taurus* cattle weighing 450 kg and eating 10 kg dry feed per day drank 28, 41 and 66 litres of water per day when the temperature is 4, 21 and 32°C, respectively (Maynard et al. 1981). Not only high ambient temperature, but cold weather also influences water intake. Cold weather may reduce water intake. This reduces water flow through the bladder and kidneys and reduced water flow allows kidney stones to precipitate. When desirable weather returns, water intake increases. The effect of ambient temperature on water intake varies between types of livestock; breeds within the same type and acclimatised animals require less water than un-acclimatised when managed at high ambient temperature. The direct effect of climate on the water intake of livestock is, however, very complex and the relationship between increased water intake of livestock with increasing ambient temperature is not simple (Winchester 1964).

The type of feed plays a decisive role on water intake. Inclusion of legumes into tropical diets was found to cause an increased water requirement (Zewdu 1991). This is because water consumption increases with the level of roughage intake and its nitrogen content and with the intake of other feeds that have laxative properties. Sheep reportedly require more water on high- than on a low-protein diet, since the nitrogenous end products require a larger urine volume for excretion (Wilson 1970; Bass 1982; Banda and Ayaode 1986; Nuwanyakpa et al. 1986; Abdelatif and Ahmed 1992; Sirohi et al. 1997). Similarly, higher proportions of salt or other minerals in the diet of sheep can result in more urine excretion and, accordingly, more water requirement (Wilson 1970; Abdelatif and Ahmed 1992; Sirohi et al. 1997). Studies with poultry have shown an increase in water consumption due to increases in the fat, protein, salt or potassium contents in the diet.

It is generally agreed that water requirements are correlated with feed intake; as feed intake decreases or increases, there is a concomitant change in faecal, urinary and evaporative water losses and, accordingly, in water requirement (Wilson 1970; Degen and Young 1981; Abdelatif and Ahmed 1992; Sirohi et al. 1997). Because of the close, direct relationship between dry matter and water intake, it has been customary to express water requirements as a ratio of dry matter intake. Such observation was a reflection of the composition of the ingested dry matter, ash and in particular nitrogen. Given the strong relationship between feed and water intakes, any feed improvement/supplementation strategy should also consider the availability of water, or supplementation would rather exacerbate dehydration and physiological stress at times of water scarcity. However, the potential benefits of water economy should be realised in relation to productive parameters, because there would be a trade-off between water saving strategies and production.

Existing published knowledge on factors of water requirement and turnover in the tropics often relates to small ruminants and lacks information on the relationship among water, dry matter intake, milk yield and other metabolic effects in large ruminants. Ayantunde et al. (2001) derived the following equation in estimating water intake (WI) for tropical cattle fed with fibrous diets in dry regions of West Africa:

$$WI = \left[\frac{492(\pm 32) \times DMI + 397(\pm 28) \times LW^{0.75}}{1000(r = 0.98)} \right]$$

In Ethiopia, there are only few studies carried out on water turnover for instance in the highlands, involving Boran cattle at Abernossa Ranch (Nicholson 1987) and Blackhead Ogaden sheep at Jijiga (Zewdu 1991). Feed resources available in the highlands are mostly crop residues that are bulky and of poor digestibility (Said et al. 1993). A study on water turnover in Boran and Boran × Friesian cows at the ILRI Debre Zeit Research Station (Janet et al. unpublished data) showed that the total water intake in early and late lactation was 49.2 and 54.0 kg/cow per day, respectively. The major part of the difference comes from a difference in drinking water intake although the higher feed intake of the late lactating cows was accompanied by a significantly higher extra water intake (+0.1 kg/cow per day). The mean amount of metabolically generated water accounted for 3.1 kg/cow per day. Water turnover, including water intake and metabolically generated water was also lower in early (52.3 kg) than in late lactation (57.1 kg; Standard Error Mean (SEM, 1.53)). The percentages of total water excreted through faeces, urine and milk were 38.0, 17.0 and 13.8%, and 45.0, 19.3 and 8.2% in early and late lactating cows, respectively.

Low milk yield in late lactation resulted in high water excretion via faeces (and urine). The ratio of water excreted to water intake showed no change between stages of lactation. The overall relation of water turnover to DM intake was 5.67 (±0.187). The quantity of water consumed was with the range of 3.5 to 5.5 kg of water per kg of dry diet given for ambient temperatures between –17°C and 27°C. The overall water turnover rate of cows was 408.3 g/live weight per day, which was also in agreement with values calculated for purebred zebu and western breed cattle (Roubicek 1969). Although occasionally extremely deviating water intake and turnover rates are observed in tropical cows, variation between animals remained astonishingly low, illustrating that estimates should be valid for a great part of the population under the conditions of the study.

Water stress

Limitations on water intake depress animal performance quicker and more drastically than any other nutrient deficiency. Water deprivation affects feed intake (Steiger et al. 2001), metabolism and productivity. Domestic animals can live about sixty days without food but only seven days without water. The provision of adequate quantities of clean drinking water is a major prerequisite for satisfactory milk production, growth and animal health (Little and Shaw 1978), but the minimum amount required is affected by various factors and therefore seldom known exactly. There is no consensus on the frequency of drinking to livestock. Usually, it is suggested under hot climate, cattle should be watered every day and sheep and goats may be watered every second day. In the eastern lowlands of Ethiopia at Jijiga, Zewdu (1991) found that Blackhead Ogaden sheep, watered once every three days, could save 34% more water without any adverse effect on performance when compared with daily *ad libitum* watering regime. Nuwanykapa et al. (1986) also concluded that watering highland sheep once every three days instead of *ad libitum* is an economical and labour-saving 'drought response' watering frequency. Pallas (1986) quoting the study made in Niger indicated that water intake every second day may be profitable for cattle when the distance from the grazing areas located 10 km away from the water supply. However, in pastoral areas the distance between grazing and water is so big and animals often have to walk long distances. Camel has an outstanding capacity to withstand infrequent watering interval. Camel can withstand the loss of up to 27% of its body weight and is able to drink exceptional quantities of water at a time. There are some indications that goats will survive better when food is in short supply provided sufficient water is available and sheep suffer comparatively severe hyperthermia relative to goats.

In moisture stressed areas, the major problems are seasonality of the pasture, the possibility of low nutrient intake and water deprivation during the dry season. In dry season, the nutrient content of available feed may decrease and this may lead to further decrease in voluntary DM intake and physiological problem in maintaining body temperature. The cumulative effects are the nutrient intake of the animals would be inadequate and thus has a pronounced effect on production and productivity of the animals in this environment. In extreme cases, signs of dehydration can occur which can be seen as tightening of the skin (skin folds), loss of weight and drying of mucous membranes and the eyes.

Importance of water quality for livestock production

There is a significant amount of knowledge regarding chemicals found in water supplies and their effect on livestock. The total salt content of water is regarded as one of the major important characteristics that may reduce suitability and palatability of water. The expression Total Dissolved Solids (TDS) is often used to denote the level of water salinity. Commonly present salts include: carbonate, bicarbonates, sulphates, nitrates, chlorides, phosphates and fluorides. High levels of specific ions in water can cause animal health problems and death. Substances that are toxic without much effect on palatability include nitrates, fluorine and salts of various heavy metals. Excess fluoride causes degeneration of the teeth. One gram of sulphate per litre may result in scours. Salts such as sodium chloride change the electrolyte balance and intracellular pressure in the body, producing a form of dehydration. Salts also place a strain on the kidneys. The National Academy of Sciences offers upper limits for toxic substances in water (Table 3) and levels of total solids and effect on livestock and poultry are given in Table 4.

Table 3. *Recommendations for levels of toxic substances in drinking water for livestock.*

Constituent	Upper limit	Constituent	Upper limit
Aluminium (Al)	5.0 mg/L	Lead (Pb)	0.1 mg/L[1]
Arsenic (As)	0.2 mg/L	Manganese (Mn)	No data
Beryllium (Be)	No data	Mercury (Hg)	0.01 mg/L
Boron (B)	5.0 mg/L	Molybdenum (Mo)	No data
Cadmium (Cd)	0.05 mg/L	Nitrate + nitrite (NO_3–N + NO_2–N)	100 mg/L
Chromium (Cr)	1.0 mg/L	Nitrite (NO_2-N)	10 mg/L
Cobalt (Co)	1.0 mg/L	Selenium (Se)	0.05 mg/L
Copper (Cu)	0.5 mg/L	Vanadium (V)	0.10 mg/L
Fluorine (F)	2.0 mg/L	Zinc (Zn)	24 mg/L
Iron (Fe)	No data	Total dissolved solids (TDS)	10,000 mg/L[2]

1. Lead is accumulative and problems may begin at threshold value = 0.05 mg/L.
Sources: NAS (1972), Ayers and Wescot (1976).

Highly mineralised waters (high solids) do not have much effect on health as long as there is no objectionable continuing laxative effects and as long as normal amounts of water are consumed. High salt concentrations that are less than toxic may actually cause an increase in water consumption. Animals may refuse to drink high saline water for many days, followed by a period where they drink a large amount. They may then become sick or die. The tolerance of animals to salts in water depends on factors such as water requirements, species, age, and physiological condition, season of the year and salt content of the total diet and the water. Animals, however, have the ability to adapt to saline water quite well, but abrupt changes from water with low salt concentration to high concentration may cause harm.

Table 4. *The use of saline waters for livestock and poultry.*

Total dissolved solids in water (mg/l)	Comments
<1000	These waters have a relatively low level of salinity and should present no serious burden to any class of livestock or poultry
1000 to 3000	These waters should be satisfactory for all classes of livestock and poultry. They may cause temporary and mild diarrhoea in livestock not accustomed to them or watery droppings in poultry (especially at the higher levels), but should not affect their health or performance
3000 to 5000	These waters should be satisfactory for livestock, although they might very possibly cause temporary diarrhoea or be refused at first by animals not accustomed to them. They are poor waters for poultry, often causing watery faeces and (at the higher levels of salinity) increased mortality and decreased growth, especially in turkeys
5000 to 7000	Avoid the use of these waters for pregnant or lactating animals even if non-lactating dairy and beef cattle, sheep, swine and horses may tolerate these salinity levels. These waters are not acceptable for poultry, almost always causing some type of problem, especially near the upper limit, where reduced growth and production or increased mortality will probably occur
7000 to 10,000	These waters are unfit for poultry and probably for swine. Considerable risk may exist in using them for pregnant or lactating cows, horses, sheep, the young of these species, or for any animals subjected to heavy heat stress or water loss. In general, their use should be avoided although older ruminants, horses, and even poultry may subsist on them for long periods of time under conditions of low stress
> 10,000	The risks with these highly saline waters are so great that they cannot be recommended for use under any conditions

Source: Peterson (1999).

The microbial quality in drinking water can also be important. There are many micro-organisms in water supply; most of them are quite harmless. There are, however, certain organisms where caution should be used. Green scum that builds up in livestock drinking troughs and tanks is algae. Some blue-green algae are toxic. Most blooms of blue-green algae contain either brain toxins (neurotoxins) or liver toxins (hepatotoxins). Just over 1 litre of water can be fatal to a 100 kg calf, depending on the toxin present in the blue-green algae bloom. No good method exists to predict whether the algae will produce the toxins. The only practical way is to monitor livestock behaviour when algae bloom heavily. Occasionally putting baking soda in water troughs will help prevent algae growth. Copper sulphate or other commercial copper containing products will also kill the algae for a period of several months. In troughs or small tanks, a safe dosage is one level teaspoon of copper sulphate per 1500 gallons of water. Generally, treatment is done only when algae growth is heavy or if a toxicity problem occurs. Livestock should be allowed to drink the treated water source at least after 24 hours. One of the most effective ways to avoid problems with blue-green algal toxins is to water cattle out of troughs rather than direct watering.

Knowledge of the effects of disease-causing micro-organisms on livestock is limited. However, to achieve benefits in terms of herd health and performance, one must avoid contamination of watering supplies for livestock and possibly treating water supplies to ensure that the water is clean or contains only low concentrations of disease-causing micro-organisms.

Impact of livestock production practices on water quality and forage availability

Water quality parameters related to livestock management include nutrients (nitrogen and phosphorus), micro-organisms (e.g. bacteria, faecal coliforms, *Cryptosporidium*, *Giardia* and organic materials such as livestock waste. Water quality concerns include impacts on receiving streams and aquatic life, and reuse of the water downstream for agricultural, recreational and drinking water (Cooke 1997).

Watering practices that can impact water quality include destruction of riparian ecosystems through over-grazing and direct cattle access to waterways. Belsky et al. (1999) in their review have shown the impacts of grazing on water quality and quantity. Water contamination from grazing includes increased sediment and bacterial counts in runoff. High runoff is due to the compaction of the soil from cattle's hooves and grazing practices.

Direct access to water sources for cattle allows for direct deposition of wastes and increased erosion. Waste management and disposal can also impact water quality. Localised concentration of animal waste is considered a point source of pollution for surface or ground water. Mismanagement or improper storage of animal waste can contaminate water sources. Ground water contamination can result from infiltrated livestock wastewater. A study in North Carolina investigated nutrient runoff from animal waste as the source of surface water contamination that resulted in large blue-green algal blooms, fish kills and declining commercial and sport fisheries. Flushed manure into ponds caused high ammonia concentration and high biochemical oxygen that resulted in a fish kill. Higher stream temperatures reduce the survival of some aquatic organisms. Livestock use can also increase in stream temperatures (Cooke 1997).

In Ethiopia, the potential causes of environmental degradation and pollution and their effect on extent aquatic resources is not documented. The potential source of major pollutants affecting Ethiopian lakes and rivers are factories, agriculture and sewage. Recent survey work on 16 industries with respect to their practices of discharging of effluents indicates that only two of them are not discharging effluents of various contents to water bodies (Table 5).

Table 5. *Industries using and discharging effluents of unknown content to water bodies.*

Factories visited	No. of factories	%
Discharge treated effluents to surface waters	6	37.5
Discharge untreated effluents to surface waters	8	50.0
Discharge not released to water bodies	2	12.5
Total	16	100

Source: EARO (2001/02).

Water is a major determinant of livestock distribution in rangelands. Animals graze from a water point to a distance they can afford depending on the availability of forage and their dependency on water. Many authors have reported changes in rangeland conditions around water points. The impact of over-grazing and trampling shows a pattern of decreasing effects with distance from the water. It is reported that heavy grazing pressure and trampling in the vicinity of the water point killed sensitive perennial grass species resulting in a zone dominated by annual plants. Problems of the impact on rangeland condition near water points are likely to cause soil erosion because of the reduced protection of soil surface during the dry seasons and enhanced bush encroachment. If livestock are allowed to overuse watering points, an impact on the vegetation is expected, or cannot be avoided.

Increasing water access to livestock

Improvement of water resources has a significant impact on the livelihood of farmers and improving the productivity of the animals. Water availability for livestock is critical in the lowlands. Most of the year, animals have to walk long distances in search of water, and are usually watered once in two to three days. The effect of water stress can be simply stated in the energy loss in long distance walking in search of water and low nutrient intake. Water stress is also pronounced in highland areas of the country especially in areas that receive low rainfall (both in amount and distribution).

Animals that are economical in water consumption and efficient for meat and meat production are highly desirable in drought prone areas. Increase in total body water content in animals under hot climatic condition is considered an adaptive reaction to ameliorate heat stress. Heat-tolerant animals are those that manifest the least changes in most of the physiological functions including body water content when subjected to a hot climate. Thus selections of animal that have such characteristics are desirable for breeding in hot desert areas. Pastoralists in Ethiopia select breeding camels based on their ability to withstand drought (shortage of feed and water) and resist diseases (EARO 2001/02).

There are a number of ways of increasing water availability, including construction of wells, pumps, canals, boreholes, tanks, cisterns, reservoirs, water yards, dams and water-harvesting systems. Selection of the method in increasing the water availability should be based on the production system and socio-economic situation of the farmers. The rehabilitation and up keep of water sources are usually a challenge in most of the areas. The process for developing water points for farm communities need to incorporate equitable arrangements for sharing the water and facilities, and account for the legal framework of use as the potential for conflict is high. The role of institutions such as community-controlled co-operatives or herders' associations and mode of operations for efficient utilisation of water resources need attention.

It should be stressed that water economy has significant implications for ruminant animal production where and when water supply is limited in total amount and/or frequency of distribution. The limited availability water, especially during the dry seasons, compels herders to economise water use in livestock production. One possibility would be to control factors that aggravate water requirement of animals, so as to save water and serve more animals on a daily basis. During adverse conditions, such as drought, when water is required for survival than production, such water saving option will help more animals survive and transit dry/drought periods to normal and rainy seasons.

Research areas

The following research issues warrant future action:

- water in the physiological ecology of ruminants: There is a need to develop water requirement for the different class of animals under their own environment. This will assist in designing management practices based on demand of the livestock farming and available resources. Water resource utilisation programme should take into account the current and future demands of livestock and fish production and productivity
- appropriate water source selection, management and protection of these sources are all critical issues to ensure that a safe water supply is used for livestock. It is necessary to define the standards of quality required for each particular use to determine the degree of pollution control necessary and to forecast the probable effect of augmented or new discharges of effluents. Establishment of water quality criteria for freshwater fish need to be undertaken
- aquatic resource laws should be developed to incorporate a system of user rights and to control access to productive waters. Legal arrangement should address all the different uses of aquatic ecosystems including fisheries, aquaculture, waste disposal and recreation. They should address the ownership of the resources and the surrogates (for example, sites, stocks, waste emissions levels) that can be used in each production system to support quantitative use right. They should define the mechanisms (economic, administrative, collective) and the structure required for allocating use rights to optimise use and ensure conservation of resources
- improve water sources such as utilisation of water harvesting techniques, developing water holes etc. and management practices to improve the utilisation
- define number and spatial distribution of water points in the rangeland; expanding and improving the network of water points
- selection and breeding animals for drought tolerance and
- community empowerment for effective range and water resources.

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