INCREASING WATER PRODUCTIVITY: LIVESTOCK FOR FOOD SECURITY AND POVERTY ALLEVIATION

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Summary

Water plays an important role in livestock productivity. Livestock productivity in pastoral areas depends greatly on the availability of water. There are several factors, which determine water balance, water turnover and functions of the animal. Assessment of livestock and water requirement is helpful in modelling water and livestock relationships.

The fate of the earth

During the latter half of this century, the pressure on natural water resources in many regions of the world has been increasing dramatically. Currently humans are extracting about half the 12,500 cubic kilometres that are readily available. Demand is now growing at twice the rate of population increase and accelerating. This can be attributed to the rapid growth in urban sprawl, the increased pace of industrialization, agriculture and irrigation development and pollution.

The earth may be the midst of a planet working cycle, but in startling departure from global trends, temperatures on Antarctic contribution have fallen steadily (Sansom 1989: Jones 1995; Hansen et al., 2000). More alarming is the fact that glaciers across the Himalayan and Hindu Kush Mountains as well as the Tibetan plateau are receding. Recent surveys show that the water level in Eling and Zhaling Lakes is decreasing. The main source of yellow river in northern Tibet was low 4.3 m level in 1993. The flow rate has also fallen drastically from 7.8 m^3 / sec –2.7 m^3 /sec (Adhikary 1999).

Hansen and Sato et al., (2000) predicted that the earth is getting warmer which is associated with an increasing green house effect and within the next decade there should be a noticeable increase in the frequent draught. The earth's average surface temperature has increased by 0.65 ^{o}C per decade during from 1996-2000, and the earth's average surface temperature will warm 0.65 ^{o}C –0.75 ^{o}C by 2050 (Michaeles and Balling 2002). As result, carbon dioxide proves beneficial for aquatic plants as well as land-based flora (Ojala et al., 2002).

The hydrological cycle

Rain and snowfall bring to earth freshwater called blue water, which is harvested for numerous activities (Table 1 and 2). This blue water runs on the ground, flows in the rivers, lakes, and oceans, infiltrates the soil, and then evaporates to create clouds, which condense to form rain and snowfall again. These processes are interlinked in a complex, continuously evolving global system called the hydrological cycle. Socio-economic and environmental activities on this planet are entirely dependent on this system, which distributes freshwater independent of human will. The system sustains life but also imposes the threats of drought and flood. Human activities such as industry, agriculture, irrigation, and rural and urban settlements are therefore naturally dependent sub-systems. These sub-systems have a heavy impact on the system, often with negative consequences on, the quantity and quality of available water, climate change, environment and biodiversity (Pirot et al., 2000).

The amount of water in the world is limited, and water covers about two-thirds of the Earth's surface, but most of it is too salty for use. Only 2.5% of the world's water is not salty, and two-thirds of that is locked up in the icecaps and glaciers. About 20% is in remote areas, and much of it arrives at the wrong time and place, as monsoons and floods. Less than 0.08% of all the Earth's water is available for humans and over the next two decades our use is estimated to increase by about 40%. About 70% of the water we have is used for agriculture. By 2020, additional 17% more water is needed than is available now if we are to feed the world.

Table 1. Global hydrological cycle.

Hydrological cycle	Water km^3
Precipitation to land	119000
Precipitation to ocean	45800
Run off from earth surface	427000
Ground water runoff to ocean	2100
Evaporation from ocean	502800
Evaporation from land	74200

Source: U.S. Geological Survey, 1984.

Table 2. Estimate of the water balance of the world.

Parameter	Surface area ($km^2 \times 10^6$)	Volume ($km^3 \times 10^6$)	Volume (%)	Equivalent Depth (m)[a]	Residence Time
Oceans and seas	361	1370	94	250	~4000 years
Lakes and rivers	1.55	0.13	<0.01	0.007	~10 years
Swamps	<0.1	<0.01	<0.01	0.007	1-10 years
River channels	<0.1	<0.01	<0.01	0.003	~2 weeks
Soil moisture	130	0.07	<0.01	0.13	2 weeks- 1year
Ground water	130	60	4	120	2 weeks-10000 years
Icecaps & glaciers	17.8	30	2	60	10-1000 years
Atmospheric water	504	0.01	<0.01	0.02	~10days
Biosphere water	<0.1	<0.01	<0.01	0.001	~ 1 week

Source: Nance (1971).
[c]Computed a through storage were uniformly distributed over the entire surface of the earth.

Water shortages set to grow

By 2025 water demand will be determined mainly by population, technology, trade and the environment. The water demand will be high in the semi-arid and arid developing countries where demographic growth will be greatest. High population will drive the need for technologies for improving water-use efficiency, as water becomes a limiting factor in the process of increasing food production, industrialization and maintaining the environment. Advanced technologies will enable some countries to use scarce resources to produce high-value products which can be traded for food grown by more water endowed countries, thereby enabling them to move away from the policy of food self-sufficiency to one of food security. In addition wastewater treatment technology to reduce agricultural and industrial pollution will also play a major role in shaping the future supply of freshwater as pollution saps the potential for growth by damaging human and environmental health. Most of the water shortages in East Africa will come due to Environmental change due land degradation and inefficient water harnessing in the rainy season (Table 3).

Table 3. Ethiopian River Basins and their water yield.

River basin	Area (Km^2)	Annual flow (billion m^3)
Abbay *	199,812	52.62
Baro-Akobo*	76,000	23.24
Tekeze*	86,510	8.20
Omo-Ghibe*	79,000	16.60
Rift Valley	52,000	5.64
Awash	110,000	4.90
Wabi Shebelle	200,214	3.16
Genale Dawa	168,100	6.10
Ogaden	77,100	0
Danakil	64,380	0.86
Aysha	2,223	0
Mereb *	5,893	0.65
Total	1,121,232	121.97

Sources: MOWR, 1997.

Water and human health

Contaminated water supplies cause more than 90% of water-related deaths. Some 2.5 million people die from unsafe water every year. The quality of water remains one of the most pressing issues in the world. Much of the population in the big basins of developing countries is exposed to contaminated water and serious waterborne diseases such as *cholera* and *schistosomiasis* (or *bilharzias*) are endemic. Population takes water from streams, lakes, ponds, or springs. Water from wells is equally contaminated, as most of them are shallow. Similarly, piped water is also unsafe in many parts of the developing countries, because water is pumped from lakes, ponds, streams, or rivers and delivered in residences completely untreated. Coverage of the population with access to adequate sanitation remains low due to low-income, informal settlements, which are often considered illegal and therefore have no rights to sanitation services. A result, morbidity due to preventable water and sanitation related disease remains high (Sitali, 1997; Howard et al, 1994).

Rapid urbanization, poor and inadequate sanitation in the cities of the developing countries, and over-crowding and congestion have led to the development of slums, which in turn have further worsened the sanitation and health problems in the city. The provision of water and sanitation facilities has consequently fallen behind population growth and community expansion. For the majority of the inhabitants in urban centers, open defecation is a common practice. People use all kinds of means, including the wrapping of human excreta in polythene bags, commonly referred to as precious package for disposal, sometimes over rooftops. People also defecate along beaches or watercourses, gutters, etc., because of the absence of usable toilets in the home or even conveniently located near the home (Allan 1997).

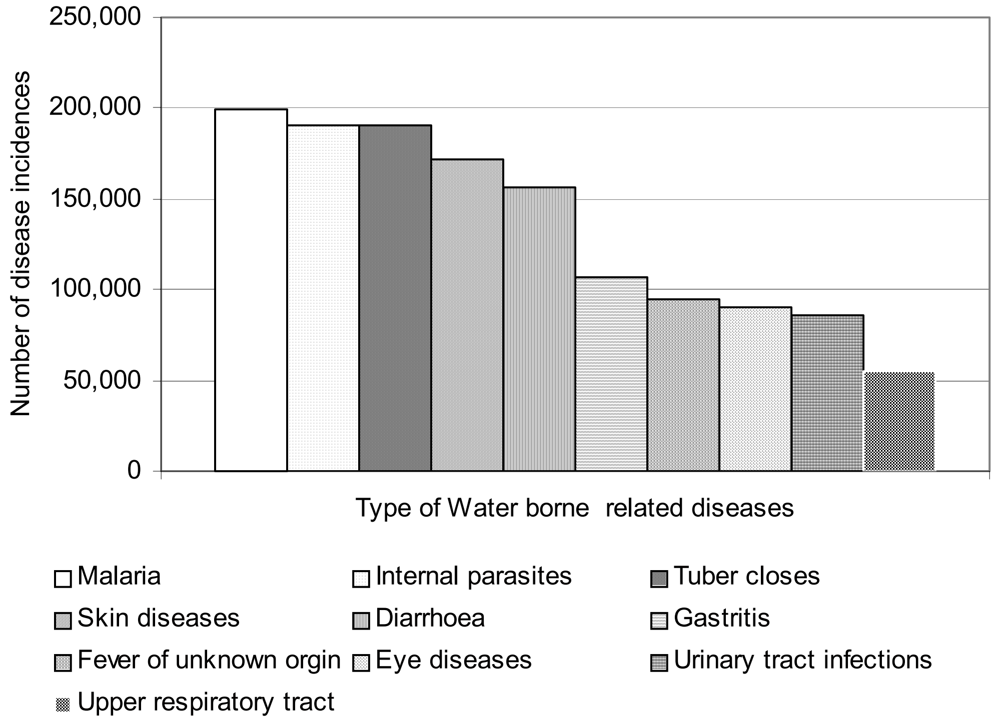


Fig. 1. Water related diseases in the Blue Nile Basin, Amhara Region, Ethiopia (MOWR, 1997).

Water quality

Increases in water use and degradation of water quality are putting extreme pressures on water resources. Water shortage has great impact on the available water to provide food, safe environments, health, and livelihoods to a growing world population, in harmony with nature. Recognizing the vital role of healthy ecosystems in the water cycle and protecting them should form the basis of any water management decision (IUCN 2000). Groundwater contamination with arsenic and fluoride and increasing pollution of surface water with waste from urban areas are major water-quality problems. The growing worldwide scarcity of good-quality fresh water makes it essential to bridge the gap between the different sectors involved in water-resource management (Van der Hoek, et al., 1999; Blumenthal, et al., 2000). Most of the water resources set for livestock and human drinking lacks water quality standards. Particularly in pastoral areas where accessibility is poor the water quality standards are unknown (Tables 4, 5, 6, 8 and 8).

Table 4 .World Health Organization and international water quality standards.

Biology [a]	European standards	International standards	European standards		International Standards
Coliform bacteria	Nil	Nil	Cyclic aromatic hydrocarbon	<0.20	
Escherichia coli	Nil	Nil	Total Hg	<0.01	<0.01
Streptococcus faecalis	Nil	Nil	Phenol compounds (in phenol)	<0.001	<0.001-0.002
Clostridium perfringens	Nil	Nil	NO_3^- recommended	<50	
			Acceptable	50-100	
			Not recommended	>100	
virus	Less than 1 plaque-forming unit per litre per examination in 10 litres of water		Cu	<0.05	0.05-1.5
Microscopic organisms	Nil		Total Fe	<0.1	0.10-1.0
			Mn	<0.05	0.10-0.5
Radioactivity					
Overall ∝ radioactivity	<3 $_{p}$Ci/l	<3 $_{p}$Ci/l	Zn	<5	5-15
Overall β radioactivity	<30 $_{p}$Ci/l	<30 $_{p}$Ci/l	Mg		
			If so_4>250mg/l	<30	<30
			If so_4<250 mg/l	<125	<125
Chemical elements/compounds			SO_4^{2-}	<250	250-400
Pb	<0.1 mg/l	<0.1 mg/l	H_2S	0.05	
As	<0.05	<0.05	Cl recommended	<200	
Hexavalent Cr	<0.01	<0.01	Acceptable	<600	
Cd	<0.05	<0.05	NH_4^-	<0.05	
Cyanidies (in CN)	<0.01	<0.01	Total hardness	2-10 meq/l	2-100 meq/l
Ba	<1.00	<1.00	Ca	75-200mg/l	75-250mg/l
F	In the case of fluorine the limits depend upon air temperature:				

Mean annual maximum day-time temperature (^{0}c)	Lower Limit (mg/l)	Optimum (mg/l)	Upper Limit (mg/l)	Unsuitable (mg/l)
10-12	0.9	1.2	1.7	2.4
12.1-14.6	0.8	1.1	1.5	2.2
14.7-17.6	0.8	1.0	1.3	2.0
17.7-21.4	0.7	0.9	1.2	1.8
21.5-26.2	0.7	0.8	1.0	1.6
26.3-32.6	0.6	0.7	0.8	1.4

[a] No 100 ml sample to contain E. coli or more than 10 coliforms.
Source: Schoeller (1977)

Table 5. Water quality criteria for trace elements and compounds.

Element/compound	Comment	Recommended limit(mg/l)	Mandatory limit (mg/l)	Unofficial Limit (mg/l)
Alkyl benzine sulphonate(ABS)		0.5		
Arsenic(As)	Serious cumulative systemic poison; 100mg usually causes severe poisoning	0.01	0.05	
Antimony(Sb)	Similar to As but less acute. Recommended limit 0.1mg/l .routinely below 0.05 mg/l; over long periods below 0.01mg/l	0.05	0.05	
Barium(Ba)	Muscule (including heart) stimulant Fatal dose is 550-600 mg as chloride		1	
Beryllium(Be)	Poisonous in some of its salts in occupational exposure			None
Bismuth(Bi)	A heavy mineral in the arsenic family avoid in water supplies			None
Boron(B)	Ingestion of large amounts can affect central nervous system	1	5	1
Cadmium(Cd)	13-15 ppm in food has caused illness		0.01	
Carbon chloroform extract(CCE)	At limit stated, organics in water are not considered a health hazard	0.200		
Chloride (Cl^-)	Limit set for taste reason	250		
Chromium (hexavalent)	Limit provides a safety factor. Carcinogenic when inhaled		0.05	
Cobalt(Co)	Beneficial in small amounts; about 7µg/day			None
Copper(Cu)	Body needs copper at a level of about 1 mg/day for adults; not a health hazard unless ingested in large amounts.	1.0		
Cyanide (CN^-)	Rapid fatal poison, but limit set provides safety factor of about 100	0.01	0.20	
Fluoride (F^-)	Benifical in small amounts; dose above 2250 mg can cause death	0.7-1.2	1.4-2.4	
Iron (Fe)		0.3		
Lead (Ph)	Serious cumulative body poison		0.05	
Manganese (Mn)		0.05		
Mercury (Hg)	Continued ingestion or large amounts can damage brain and central nervous system		0.005	
Molybdenum (Mo)	Necessary for plants and ruminants. Excessive intake may be toxic to higher animals; acute or chronic effects not well known			None
Nickel (Ni)	May cause dermatitis in sensitive people; doses of 30-70 mg of $NiSO_4$. $6H_2$ o have produced topic effects.			None
Nitrate NO_3^-	Excessive amounts can cause methemo-globinemia (blue baby) in infants.	45		
Radium (ra-26)	A bone seeking internal alpha emitter that can destroy bone marrow	3pc/l		
Selenium (Se)	Toxic to both humans and animals in large amounts. Small amounts may be beneficial		0.01	
Silver (Ag)	Can produce irreversible, adverse cosmetic changes		0.05	
Sodium (Na)	A beneficial and needed body element, but can be harmful to people with certain diseases			200
Strontium-90	A bone seeking internal beta emitter	10pc/l		
Sulphate (SO_4^{2-}		250		
Zinc(Zn)	Beneficial in the child needs 0.3mg/kg/day; 675-2280 mg/l may be an emetic		5	

Source: Schoeller (1977)

Table 6. Water quality standards for arid regions**.**

	Suitability for permanent supply			
	Good	Fair	Moderate	Poor
Colour	Colourless	Colourless		
Turbidity	Clear	Clear		
Odour	Odourless	Hardly perceptible	slight	slight
Taste at 20^0c	None	perceptible	pronounced	unpleasant
Total dissolved solids (mg/l)	0-500	500-1000	1000-2000	2000-4000
EC (µs/cm	0-800	800-1600	1600-3200	3200-6400
Na (mg/l)	0-115	115-230	230-460	460-920
Mg (mg/l)	0-30	30-60	60-120	60-120
$\frac{Mg}{12}+\frac{Ca}{20}$	0-5	5-10	10-20	20-40
Cl (mg/l)	0-180	180-360	360-710	710-1420
SO_4 (mg/l)	0-150	150-290	290-580	580-1150

Source: Schoeller (1977)

Table 7. Recommended mineral concentration limits for livestock

Element	Derived maximum working level (mg/l)	Element	Derived maximum working level (mg/l)
Arsenic (as As)	1.0	Lead (a Pb)	0.5
Boron (as B)		Magnesium (as Mg)	250 to 500
Cadmium (as Cd)	0.01	Mercury (as Hg)	0.002
Calcium (as Ca)	1000	Molybdenum (as Mo)	0.01
Chromium (as Cr)	1 to 5	Nitrogen (as NO_3^-)	90 to 200
Copper (as Cu)	0.5 to 2.0	Selenium (as Se)	0.02
Fluoride (as F)	2	Sulphur (as SO_4^{2-})	1000
Iron (as Fe)	10	Zinc (as Zn)	20

	Maximum total dissolved salts		Maximum magnesium
Livestock	Western Australia	Victoria	Australia
Poultry	2900	3500	
Pigs	4300	4500	
Horses	6400	6000	
Dairy cows	7100	6000	250
Beef cattle	10000	7000	250
Sheep on dry feed	13000	14000	400
Ewes with lambs	10000	4500	500
Ewes in milk	10000	6000	250

Table 8. Key water quality criteria for livestock

Substance	Upper limit	Substance	Upper limit
Total dissolved salts (mg/l)	10000[a]	Hazardous trace elements (mg/l)	
		As	0.05
Radionuclides (pCi/l)		Cd	0.01
^{90}Sc	10	Cr	0.05
^{255}Ra	3	F	2.40
Activity	100	Pb	0.05
		Se	0.01
Chemicals (mg/l)			
$MgSO_4$	2050		
NaCl	2000		
SO_4^{2-}	1000	Organic substances	
		Algae (water bloom)	-[b]

[a] Depending upon animal species and ionic composition of the water.
[b] Avoid abnormally heavy growth of blue-green algae. Parasites and pathogens coform to epidemiological evidence.

Water demand for industries

Industry accounts a quarter of water withdrawals worldwide. While developed countries have reduced use of water in industry, in the developing world industrial water usage is growing at astronomical rates. Water quality in many water sources is shifting from biological to chemical contamination (UNIDO 1997). Land reform programs tend to increase homestead densities in zoned residential areas and reduce distances between pit latrine and family wells thereby increasing the possibility of groundwater effluent pollution. Many international organizations have been involved in water policy, primarily in domestic and agricultural water supply, rural and urban sanitation (Cosgrove and Rijsberman 2000).

Irrigation

A decline in available water for irrigation without compensating investments and improvements in water management and water use efficiency-in both irrigated and rain fed areas-will reduce production growth and sharply increase international cereal prices, causing negative impacts on low-income developing countries and consumers (Rosegrant and Cai 2000; Hofwegen amd Svendsen 2000). Most groundwater experts advocate the development of comprehensive integrated management systems (Burke and Moench 2000; Foster et al., 1998; Foster, et al., 1999). In the past many irrigation projects were started with out appropriate drainage systems. As a result, inefficient irrigation systems have lead to secondary Stalinization of vast land in the developing courtiers. However, one can understand the huge potential of the East African Rivers, which are under utilized. The Ethiopian rivers are the huge water resources for future irrigation and hydropower development (Table 9), and the data in Figure 2 indicates that water resources are under utilized and water supply facilities in the region are not well developed for human consumption people.

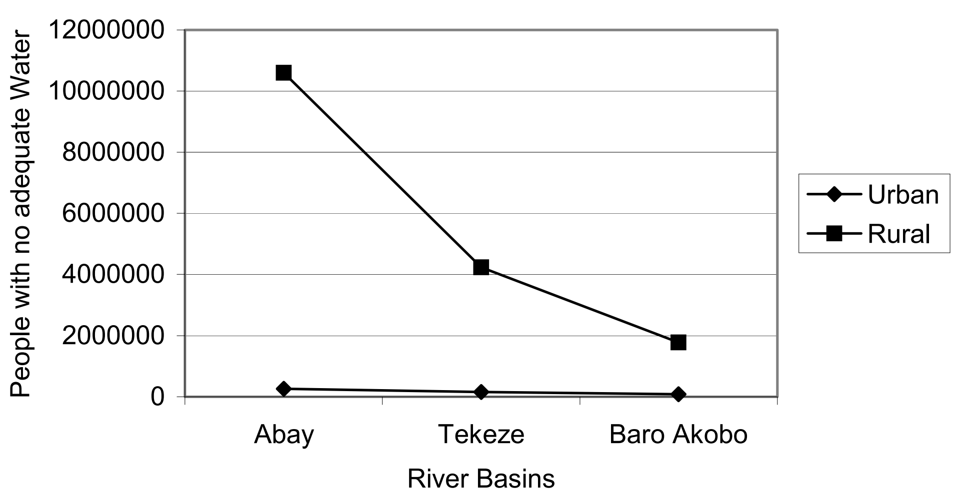


Fig. 2. Rural and urban water supply status in the Abay, Tekeze and Baro Akobo Basin, Ethiopia (Source: MOWR, 1997).

Table 9. Potential irrigable and actual irrigated area of the main drainage basins, Ethiopia.

Basins	Potential Irrigable Area (ha)	Actual Irrigated Area (ha)	% Utilized
Abay (Blue Nile)	977,915	21,010	2.10
Rift Valley Lakes	122,300	12,270	10.00
Awash	204,400	69,900	34.20
Omo-Ghibe	450,120	27,310	6.10
Genale-Dawa	435,300	80	0.02
Wabi-Shebelle	204,000	20,290	9.90
Baro-Akobo	748,500	350	0.05
Tekeze	312,700	1,800	0.57
Afar	3,000	-	-
Mereb	37,560	8,000	21.30
Total:	3,495,795	161,010	4.07

Source: MOWR, 1997

Managing water as an economic good

Water pricing policy

Enhancing and sustaining the economic and welfare contributions of water resources depends ultimately on the ability to face the twin challenges of supply augmentation with the lowest ecological and social costs, and the development of institutional frameworks for an efficient use of existing and future supplies. The future of the market-based water economy in most countries rests on how quickly the institutional reforms are undertaken (Jone 1988; Briscoe 1996; Asad, et al., 1999).
Water markets can help improve river basin management, water measurement, enforcement, sanctioning, water availability information, and water-user participation. New legislation should lay down a general framework and leave room for the elaboration of local variations in specific cultural, legal, and hydrological conditions (Pradhan, et al., 1997; Boelens and Davis 1998; Burns, et al., 2000).

Efficient utilization of water resources and human well fare

Two hundred sixty one watersheds and countless aquifers cross-political boundaries are available in the world. International basins cover 45.3 percent of the land surface of the Earth, affect about 40 percent of the world's population, and account for approximately 60 percent of global river flow. Disparities between riparian nations-whether in economic development, infrastructure capacity, or political orientation further complicate international water resources management. Therefore, development projects, treaties, and institutions are regularly seen as inefficient at best and, occasionally, as a source of new tension themselves. The water borne diseases in the up land is critical (Figure 1).

A general pattern has emerged for international basins over time and riparian of an international basin first implement water development projects unilaterally within their territory in an attempt to avoid the political intricacies of the shared resource. Pressure from the rapidly growing population is an important factor in land and water resources extraction, shifting settlements to follow water distribution is no longer sustainable in many parts of the country. Human settlements located in areas where sufficient arable land exists and where other resources are available for exploitation, and not necessarily, where sufficient water is available. Therefore, water has to be moved to where it is wanted.

Population growth, densities, and dispersion are associated with environmental degradation. The excessive removal of vegetation, the over exploitation of aquatic resources, and pollution, among other factors, have adversely affected water quantity and quality. Consequently, they limit water accessibility.

Influence of Livestock on ecosystems

Livestock grazing affects watershed properties altering plant cover by physical action of their hoofs. Reduction in vegetation cover increases the impact of raindrops. Expansion of grazing land and crop production to steep slopes in the tropical highlands changes hydrological functions unless livestock is properly managed (Mwendera and Mohamed Saleem 1996, 1997a and 1997b). The poor management of the watershed has changed the sustainability of river streams, ground water and generally the aquifers of the most susceptible regions to water shortage. The water towers of the east African highlands are changing very rapidly, unless sound water or ecosystem management is quickly launched. Livestock manure washed by runoff to water bodies is becoming acute problem.

2. LIVESTOCK WATER NEEDS

The demand for meat, dairy products and eggs rises faster than the demand for crops; thus both s scenarios call for livestock production to increase relatively more rapidly than crops. The world livestock system is broadly divided into pastoral grazing, mixed farming and industrial systems (Sere and Stienfeld 1996). Estimate of the current demand of 1.7 billion tons of cereals and 206 million tones of meat in developing countries could rise by 2020 to 2.5 to 2.8 billion tones of cereals and to 310 millions of tons of meat (IFPRI 2000).

Water is used by the herbivore as a medium for physical and chemical energy transfer, namely for evaporative cooling and intermediary metabolism (Konandreas and Anderson; King 1983; Kirda and Riechardt 1986). Livestock and poultry water consumption depend on a number of physiological and environmental conditions such as:

- Type and size of animal or bird
- Physiological state (lactating, pregnant or growing)
- Activity level
- Type of diet-dry hay, silage or lush pasture
- Temperature-hot summer days above 25 ^{0}C can sometimes double the water consumption of animals..
- Water quality - palatability and salt content

Grazing Management of pastoral system

There are many important aspects to study the livestock production system. One of the most important ways is to keep detailed records on both livestock stocking rate and performance and forage production. Forage production and stocking rate records are critical in forage productivity and livestock water consumption. Expressions such as ‘stocking density’, ‘grazing pressure’, ‘herbage allowance’, ‘grazing intensity’, stocking intensity’, ‘and stocking pressure’ have long been used to describe animal-pasture systems (Scarnecchia and Kothmann 1985).

In most cases four variables are involved in describing animal pasture relationships (Table 10 and 11). These variables are:

- The pasture area (A) in certain basin or catchments or range, usually expressed in ha,
- The forage dry matter (DM), usually expressed in animal units (AU).
- The animals’ rate of demand for forage, which might be termed the potential rate of forage, is the function of animal numbers, weight, physiological state, and other animal related factors.

An animal unit (AU) is 454 kg cow or one animal–unit equals 12 kg forage/day in animal demand. An animal that has a demand rate more or less 12 kg DM/day will have an animal–unit equivalent (AUE).

Calculations/Formulas

The AUE for Cattle of 454 kg or less is calculated as:

AUE = (BODY WEIGHT +100)/1000

Or, for animals weight greater than 454 kg

AUE = (BODY WEIGHT-100)/1000

Table 10. Animal unit equivalent (AUE) and estimated daily forage dry matter demand for various kinds and classes of animals.

Animal type	AUE	DM Demand (kg/day)
Cattle		
Callfs		
136.08 kg	0.4	4.08
181.44 kg	0.5	5.44
226.80 kg	0.6	6.80
272.16 kg	0.7	8.16
Cows	1.0	11.79
Bulls	1.25	14.52
Horses	1.25	14.52
Sheep	0.2	2.28
Goats	0.17	1.81

Table 11. Summary of relationships among variables of animal demand, forage quantity, pasture area and time.

Animal/Area	Animal/Forage	Forage/ Animal	Forage/area
Stocking rate = AUM/ha =AUM/ha	Grazing pressure Index =Ratio of animal demand to forage cover in certain period of time	Cumulative herbage allowances (Kg days/AU or ton months/AU)	
Stocking density = animal demand per unit area at any instant (AU/ha)	Grazing pressure = Animal demand per unit weight of forage at any instant (AU/kg or AU/ton)	Herbage allowances = weight of for a per unit animal demand at any instant (Kg/AU or kg/AU/hr)	Standing crop =weight of forage standing per unit area at any instant (Kg/ha or g/ m^2)
Rate of change in Stocking density (AU/ha/day or AU/ha/hr	Rate of change in grazing pressure (AU/kg/day or AU/kg/hr)	Rate of change in Herbage Allowance (Kg/AU/day or kg/AU/hr)	Net forage accumulation rate (Kg/ha/day or kg/ha/hr) Rate of Change in net forage accumulation rate (Kg/ha/day/day)

1 au = 1 animal-unit = 12 kg forage/day in animal demand
AUM is animal-unit month
Source: Scarnecchia and Kothmann, 1985.

Biomass production and Water use for pastoral grazing management

Net primary productivity (NPP) is an important index of how well vegetation lives within the ecological community at a place. NPP is the amount of living plant tissue gained by growth, less the amount lost through death or relocation, per unit area, per unit interval of time. Usually NPP is expressed as the total weight of new material in all living plants, called plant biomass, produced annually within an area. Plant growth is especially sensitive to two climatic variables temperature and moisture affect evapotranspiration. Actual ***evapotranspiration*** ***(AE)*** represents the true utility of water availability, because, AE provides a more realistic single expression of climate than either temperature or precipitation, when specifying the relationship between climate and biosphere productivity. We can predict annual NPP easily from the *annual* AE values (from a water budget) for any place where we have weather data (USEPA 1973). This can be accomplished prediction by a simple equation:

$$NPP=(2.29AE)-366.8 \quad \text{Equation (1)}$$

Where; NPP is net primary production and AE is Actual Evaporation.

In real ecological communities, there is a constant recycling of nutrients from the decomposition of litter, or dead organic material, through the soil to newly produced living biomass. The potential decomposition (and thus recycling) *rate* is also predictable, using a known relationship with AE using equation 2:

$$\textbf{Decay Time} = 1/(x/100) \quad \textbf{Equation (2)}$$

Where, x is the decay rate.

Now, let us calculate on e Example for area of Fitche in the Highland of Ethiopia.

PE = 1530 mm, Rainfall =1232 mm, and AE =792 mm

Calculation: 1.4 t/ha/year.

NPP = NPP=(2.29 x 792)-366.8 = 1446.88 g/cm^2 /year or 1.16 t/ha/year

The decay time is 10 %; hence 0.12 t/ha/year biomass will go to decay, and about 1.16 t/ha/year – 0.12 t/ha/year = 1.4 t/ha/year of biomass could be produced. What could be the water utilized for the production 1.4 t/ha/year? If we relate the AUE to DM demand by each livestock species it is really possible again to calculate the water consumed Table 5 and 6 we can relate the animal/forage or forage/animal need which leads to us to the water modelling for Basin/watershed and water consumed by animals through the feed.

Poorly managed grazing systems and overgrazing cause sever soil losses and huge runoff due to soil compaction and less vegetative cover. The data in Figure 3 showed that the runoff from heavily grazed plots was very high. The infiltration rate on the grazed plots is very low that is 2.5 cm/hr. From the data, one can easily judge that the infiltration rate on the grazed plots is very low due to livestock trampling (Taddese et al., 2002).

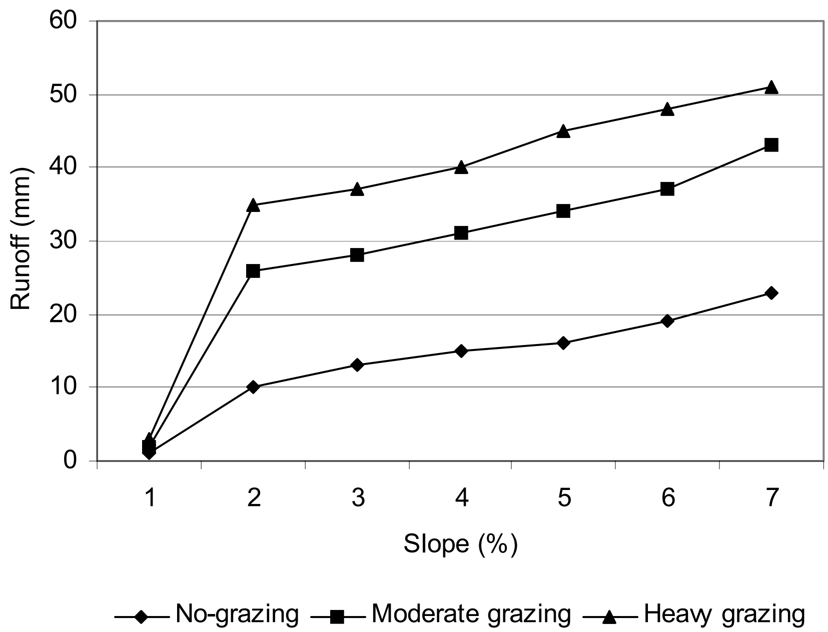


Fig. 3. Effect livestock grazing on the runoff (at 335 mm of rainfall) in mixed farming systems of the Ethiopian highlands.

Estimating crop residue and available for grazing

Mixed farming occurs in many forms and it has been around in many countries since the start of agriculture (Hans and Kater 2001). Utilizing livestock to consume excessive residue is an efficient way to manage crop aftermath. Knowing the quantity of residue initially available and how much residue should remain to provide adequate protection of the soil allow the producer to determine how much residue is available to be consumed by livestock. In the Ethiopian highlands of mixed farming systems farmers use crop stalk as supplement feed for their livestock. The role of Crop residue is increasingly becoming very important where grazing land is shrinking (Abiye Astatke and Mohamed Saleem, 1995, 1998).

Estimation of water content in the crop residue and utilization is possible from Table 12. There are several ways to determine the amount of residue on a particular field. The methods can range from scientifically measuring the amount of residue on a field to simply calculating the quantity of residue produced based on harvested grain yield. The initial evaluation of residue quantity is important to estimate the quantity of feed available to livestock. An easy way to estimate pounds of residue is to make a template from pliable rod or material. A second method to estimate the quantity of residue present is based on calculations with residue index (***Residue index = kg of residue produced/kg of grain produced***). The water requirement of the crops can be estimated from CROPWAT (FAO 1999).

Table 12. Typical crop residue yield and water content of the Ethiopian farmer.

Type of feed	Yield (kg/year)	% Water in 100 kg	Water kg/year
Teff straw	427	14	59.78
What straw	171.2	16	27.392
Rough pea straw	92.6	16	14.816
Chick pea straw	22.6	14	3.164
Maize stover	1970.6	65	1280.89
Corn-cob	302.4	34	102.816
Teff aftermath	127.5	49	62.475
Wheat aftermath	76.2	29	22.098
Hay	179.3	9	16.137
Grazing natural pasture	3506.7	65	2279.355
Browse	2.7	65	1.755

Source: Getachew Eshete, 2002

Grazing Systems

The grazing system is dependent on the natural productivity of grasslands and defined largely by the agro-ecological zone. Rangeland and pastures are available as open or common access to communities of livestock farmers. This resource allows a wide range of flexibility to lead animals seasonally to the best pastures and to reach during the dry season (Stephen Sanford 1983; Solomon Bekure et al., 1999).

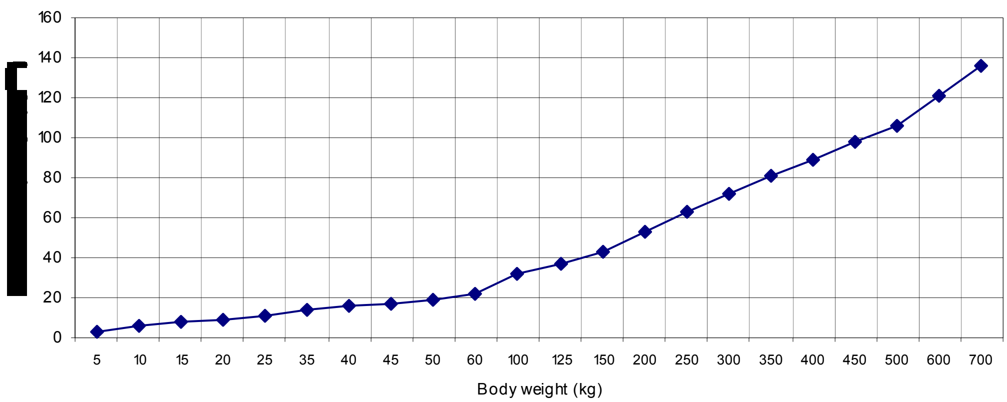
Grazing systems

Mobile grazing systems: where pastorals can move animals to use grasslands and browse extensively over wide areas. The mobile grazing systems are characterized by annual or seasonal movements of a part or the entire human group with the livestock to new places following the availability of water and pasture resources. The two main types of stock mobility: nomadic and transhumance.

Sedentary grazing systems: on communal grasslands: the stock farmers, permanently resident, use communal pastures extensively.

Ranching and grassland farming: the ranchers and stock farmers are permanently resident and control the more or less extensive use and management of grasslands. Mixed farming is practised in nearly all Agro Ecological Zones: from rainforests to oases in arid zones, but the environment, impacts are more closely related to the source of the feed than to the difference between zones.

Industrial systems are directed for market demand, with intensive animal production and processing, which takes place near urban areas. Since livestock is confined in ranches production techniques are independent of the agro-ecological zone and of the climate. The variables in the tropical rangeland can be easily calculated from the established functions (Fig. 4, 5 and 6).



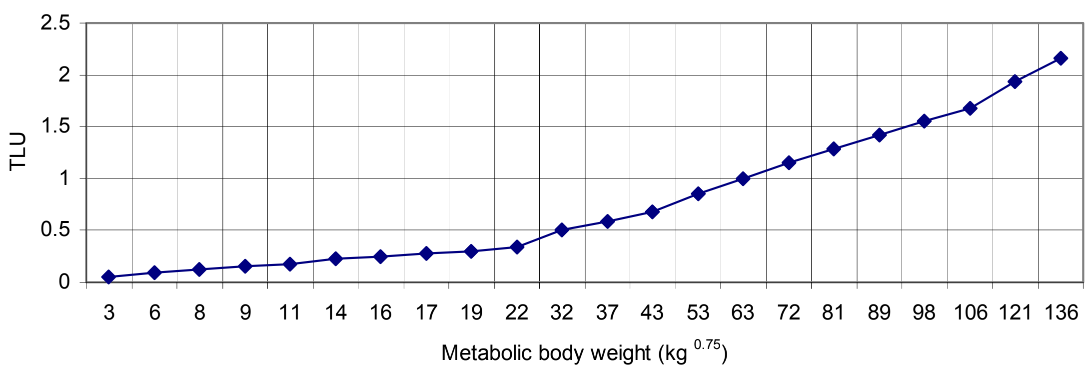


Fig. 5. Relationship between metabolic weight and Tropical Livestock Units

Fig. 6. Relationships between Tropical Livestock Units and Body Weight (kg).

Livestock water requirement at watershed/range land

Air temperature

The water requirement related to dry matter intake increases with air Temperature (Table 13).

Table 13. Water requirement and air temperature

Air temperature (in °C)	Water requirement (l/kg of DM consumed)
-17 to +10	3.5
10 to 15	3.6
15 to 21	4.1
21 to 27	4.7
more than 27	5.5
In the case of pregnant cows 1.5 multiplies the quantities and for lactating cows they are increased by 0.87 l per kg of milk produced.	

Source: Agricultural Research Council (1965)

Voluntary water intake

The voluntary water intake is the quantity of water, which has actually to be supplied to animals, and corresponds to that part of the water requirement, which cannot be provided by the moisture content of the forage. The voluntary water intake has been calculated from the water requirement by assuming a water supply from the plants corresponding to 70 to 75 percent of moisture content of the plants during the wet season, 20 percent of moisture content of the plants during the dry and cold season and 10 % of moisture content of the plants during the dry and hot season (Table 14 and 15).

Table 14. Estimated water requirement and voluntary water intake of livestock under sahelian conditions.

	Tropical	Mean	Daily dry	Wet season Air temp 27°C		Dry cold Season Air temp from 15-21		Dry hot season Air temp 27°C	
Animal	Livestock Units (TLU)	Live-weight in kg	Matter intake in kg	Total water req. in l/day	Volun. water intake in l/day	Total water req. in l/day	Volun. water intake in l/day	Total water req. in l/day	Volun. water intake in l/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

One Tropical Livestock Unit (TLU) is equivalent to an animal of 250 kg liveweight on maintenance. Moreover the animals, which spent less energy for walking were less tired and could walk faster.

Table 15. Results of observations made in Niger on two similar herds one watered every second day and the other one every day

Activity	WATER INTAKE EVERY SECOND DAY				DAILY WATER INTAKE	
	Time spent first day	Time spent second day	Daily average	Percent of total time	Time spent	Percent of total time
Grazing	6h 40	9h	7h 50	33%	6h 30	27%
Walking	7h	2h	4h 30	19%	8h 30	37%
Ruminating	4h 50	5h 40	5h 15	22%	3h 30	15%
Rest	5h 20	7h 20	6h 20	26%	5h 20	22%
Watering	0h 10	0	0h 05	negligible	0h 10	1%
Total	24h 00	24h 00	24h 00	100%	24h 00	100%

Source: Serres (1980)

Over an area of 600 ha (circle of 4 km diameter), the number of Tropical Livestock Units (TLU) which should be watered from each supply is equal to 30 000 divided by the carrying capacity (C_{cap} in ha/TLU) corresponding to the average rainfall year.

Assuming maximum daily water intake of 40 l/TLU, the maximum daily requirement (V_{maxday}, in m^3/day) to be met by each water supply will be V_{maxday}, should then be compared to the amount of water expected, Q_{exp} in m^3/day, that each water supply can deliver in 12-16 hours daily operation. If V_{maxday} is less than Q_{exp}, then take 20 km as an average distance from one water supply to another.

$$V_{maxday} (m^3/day) = (600 \text{ ha} \times 40 \text{ l}) / (C_{cap} \times 1000) = 24/C_{cpa}$$

Using the same symbols as before, the maximum number of TLU, which can be watered from each supply will be:

$$TLU = (Q_{max} (m^3 /day) \times 1000\} / \text{litre} = Q_{exp} (m^3) \times 250$$

The rangeland area (in ha) necessary to feed N_{TLU} will be N_{TLU} x C_{cap} and eventually the maximum interval D_{max} between water supplies will be approximately:

D_{max} *(km) = 20 x* $\{N_{TLU}$ *x* $C_{cap}\}$*/ (1000 x 3.14)*

Rainwater harvesting techniques

Water harvesting consists of collecting and storing water from an area that has been treated to increase precipitation runoff (Abiye Astatke et al., 1986). A water harvesting system is composed of catchments or water collecting area, a water storage structure, and various other components such as piping, evaporation control and fencing.

$V (m^3) = \{A (m^2) \times P (mm)\} /1538$

Quantity of water (V), which can be collected (at 65 %) and used, after deduction of losses, from a catchment's area (A) with an average annual rainfall (P). For example If the annual water requirement for one horse is assumed to be approximately 15 m^3, including the losses around the watering troughs, the corresponding catchment's area A can be estimated by the proceeding formula rewritten as follows:

$A (m^2) = 24000/ [P (mm)]$

The rainwater harvesting in Ethiopia is a common practices. Twenty years back there were traditional private ponds were giving with services for human and livestock drink. The charges were few and mostly played in manual labour to maintain the pond and to remove the salutation. There are also communal ponds and most of the ponds belong to the peasant associations. There are also private and communal dug wells very useful in the dry season for human and cattle drink

Livestock Body weight.

Cattle require large amounts of water every day. They meet this requirement via three sources: drinking or free water intake (FWI), ingestion of water contained in feed, and water produced by the body's' metabolism of nutrients. Metabolic water insignificant source compared with the water ingested freely or in feed. The sum of FWI and the water ingested in teed is the total water intake (FWI).

Body water is divided into intracellular and extra cellular compartments. Intercellular water is the larges compartment, accounting for about two-thirds of the water in the body. The extra cellular fluid comprises water around cells and connective tissues, water in plasma, and Trans-cellular water in ht gastrointestinal tract. Loss of water from the body occurs through milk production, urine exertion, and faecal excretion, sweat and vapour loss from the lungs.

Forage intake

Konandreas and Anderson (1982) have developed the following model for forage intake.

$$I = m (d , t).m(Q).m(D).m(t).m(x, t).m(p, t).a. W_e^{-0.75}$$

I= dry matter forage intake ($kg.d^{-1}$)

M (d, t) = digestibility of forage correction multiplier = 1/(1-d), where d = digestibility between 0.40 and 0.65

M (Q) = quantity of forage correction factor multiplier ($t.ha^{-1}$), with forage on offer (Q) varying from 0.7-2.1 with threshold for intake reduction (Q^x) 0.8; mQ = 1 for values $Q \geq 0.8$ and Q/Q^x is below 0.8.

M (D) = grazing time correction multiplier, a function of the distances walked per day (D), which above 14 km (D^x) reduces forage intake by 1.0-0.05 ($D-D^x$); otherwise m (D) = 1.0.

M (t) = age correction multiplier =1

M (x, t) = sex correction multiplier =1

M (p, t) = physiological status correction multiplier, which for dry females =1, and for lactating cow =1.15, partially due to an increase in chewing and ruminating

A = intake coefficient (kg DM.$kg^{-0.75}$ .d^{-1}), which is equivalent to the rate of passage, and taken as 0.042 for dry cows and 0.049 for lactating cows

We =expected live weight (kg) for animals age and sex

Energy use

Energy demands vary with the body functions for which energy is used. T the net energy (NE) is demanded for lactation, growth back to maintenance energy (ME).

Animals dissipate heat by evaporation, radiation, convention, and conduction. Heat energy (HE) essentially independent of temperature and is determined by feed intake and the efficiency of use; body temperature control primarily via regulation of heat dissipation. When effective ambient temperature increases above the zone of upper critical temperature (UCT) productivity decreases as a result of reduced feed intake, but energy requirements for maintenance will increase. When ambient temperature decreases below the lower critical temperature (LCT), heat Energy (HE) produced from normal tissue metabolism and fermentation is adequate to maintain body temperature. This increases animal metabolism to provide adequate heat to maintain body temperature.

Thermo-neutral conditions of the animals may differ substantially as functions of feed intake, physiological state, genotype, sex and activity, and depends also on acclimatization of the animal that is adaptively to climate conditions, behavioural and physiological changes. The National Research Counsel (NRC 1980) reported that the required Net Energy (NE) of the cattle adapted to the thermal environment is related the previous ambient (air) temperature (T ^oC) in the following manner:

$$NE = \{(0.0007) \times (20-T_p)\} + 0.077\ Mcal/BW^{-0.75}$$

This equation indicates that the NE requirements of cattle change by 0.077 $Mcal/BW^{-0.75}$ for each degree that previous ambient temperature differed from 20 ^oC. The combined effect of temperature and humidity has been developed into an index (THI) by the Untied States Weather Bureau to describe applicable to animals (McDowell 1972).

$$THI = 0.72\ ({}^{o}C_{db} + {}^{o}C_{wb}) + 40.6$$

Where db = dry bulb temperature in ^{o}C, and wb = wet bulb temperature in ^{o}C

Body Turnover

If the animal is not lactating and walking a great distance the following formula may use (Edwards et al., 1983).

$$W_F + W_d = TBW_T - (W_M + W_{RC})$$

W_F =Water from food
W_D = water drinking
TBW_T = total body weight
W_M = metabolic water
W_{RC} = respiratory coetaneous water

Conclusion

Water resources are finite and very susceptible tot degradation, and therefore production and management systems to cater for the livestock systems need to be based on quantitative data on water resources endowment and their response to livestock productivity. Modelling livestock water needs and different functions of livestock water use is very important. Moreover, livestock production to hydrological response needs more attentions in the fragile ecosystems river basins and rangelands.

Recommendations

The following points are very important to be considered in relation to livestock water:

- Study livestock water use for different pastoral systems.
- Study rainfall and livestock water use at watershed and household level.
- Study the pathways for water use by livestock through food intake.
- Relate all water factions to water accounting and water productivity.
- Develop model and tools for livestock water productivity at river basins and watershed level.

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